The Puget Sound/Georgia Basin Ecosystem:
Status, stressors and the road to recovery

Abstracts of Oral Presentations

ORAL PRESENTATION SESSIONS

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SESSION 1A: PUGET SOUND REGIONAL SYNTHESIS MODEL (PRISM), ROOM 407-409

A Seamless Digital Physiography and Data Model for a Regional Coupled Model

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A Hydrometeorology Model of Puget Sound: Water from the Atmosphere Across the Land Surface

Ken Westrick
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Ocean Dynamics: Water Masses and Ecosystem Properties in Puget Sound

Mitsuhiro Kawase
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Water Resources Allocation Model for Regional Decisions

Richard Palmer
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The Human Dimension: Coupling Projected Changes in Regional Demography to the Biophysical World

Paul Waddell
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SESSION 1B: INTERTIDAL AND NEARSHORE ECOLOGY, ROOM 405-406

Puget Sound Intertidal Biodiversity: Scales of Variability for Invertebrate and Algal Communities on Gravel Beaches

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Evidence suggests that gradients of salinity, water temperature, and wave energy, as well as environmental forcings within shoreline habitats such as substrate size, pore water chemistry, and wave energy dissipation contribute to the biological variability observed in estuaries. We quantified this relationship in 1999 by first measuring the spatial distribution of sea surface salinity and water temperature in the south and central basins of Puget Sound. We then selected three pebbles beaches (100's m apart) in each of three separate locations (1000's m apart) within each of four cells (10's km apart) of relative oceanic homogeneity. The substrate size, wave energy, and pore water chemistry were quantified for each beach. The biota on these beaches were sampled using standard quadrat and core techniques. We then compared the community structure at each spatial scale using multivariate ordinations and hypothesis tests. We also used nested ANOVA's to determine the spatial scales of variability among sites, among locations and among cells. Our results suggest a high fidelity of communities to the physical environment of the ocean and beaches at all spatial scales. Our results illustrate the power of using multiple replicates in a spatially nested design to determine biological responses to environmental forcings.

Community Structure in Goose Barnacle (*Pollicipes polymerus*) and Sea Mussel (*Mytilus californianus*) Beds off the West Coast of Vancouver Island, British Columbia

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Goose barnacles (*Pollicipes polymerus*) have been harvested off the west coast of Vancouver Island since 1985. In 1998, establishment of a sea mussel (*Mytilus californianus*) fishery was proposed. However, following introduction of the Oceans Act in 1997, Fisheries and Oceans Canada (DFO) became mandated to manage ecosystems. Consequently, establishment of a sea mussel fishery was rejected because analysis indicated that sea mussels had an important structural role in the exposed rocky intertidal ecosystem and that harvesting sea mussels would likely have significant negative impacts. This exercise also focused attention on the existing goose barnacle fishery. Since the ecological role of this structural species had not previously been thoroughly

investigated, this fishery was terminated in January, 1999, displacing a number of fishers. To address this situation, studies were commenced to evaluate both the role of goose barnacles in the exposed rocky intertidal and to evaluate the impacts of a goose barnacle fishery on the ecosystem there. In July, 2000, 29 quadrate samples of this community were collected off Ucluelet and Tofino, British Columbia. Analysis presented here is for species present, species size structure, and species associations, with comment on future planned studies.

Watch Your Step! Impacts of Trampling on a Rocky Shoreline of San Juan Island, Washington

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Rocky intertidal habitat at San Juan County Park, Washington, was experimentally trampled to assess risks of human visitation to ecological communities. For six weeks in spring, six 5 m vertical transects were subjected to augmented trampling (250 steps three times a week) in the zone dominated by the brown alga *Fucus gardneri*. These transects, plus six additional "controls", received low levels of trampling from park visitors. Densities of five taxa were recorded throughout this period and for 3 months thereafter. Repeated observations were made at three tidal elevations along each transect using fixed quadrats (20 x 20 cm). Trampling reduced cover of Fucus to 30 percent of its original value within six weeks, and cover remained lower in trampled than control quadrats throughout the "recovery" period. Trampling also resulted in a short-term decline in species richness, from an average of 8 to 7 species per quadrat. The turf-like alga *Endocladia muricata* did not respond to trampling, nor did barnacles. Mobile gastropods (limpets and whelks) also remained similar in trampled and control areas. Bare space showed a delayed response to trampling, increasing one month after trampling ceased. This study highlights a management challenge of protecting natural habitats in parks and reserves while still encouraging public access and appreciation.

The Roles of Vertical and Horizontal Gradients of Abiotic Stress in Determining Regional Intertidal Diversity Patterns in the Northwest Straits

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Ecologists have devoted much attention to large scale patterns of biodiversity. However, the mechanisms that underlie these patterns remain poorly understood. In the Northwest Straits, intertidal biological diversity decreases from the mouth of the Strait of Juan de Fuca eastward through the San Juan Islands and into Puget Sound. This diversity gradient is accompanied by trends in wave exposure, insolation, and air and rock temperatures. Increases in thermal and desiccation stress at the eastern end of the Northwest Straits force sessile invertebrates and algae to live lower on the shore. However, mobile consumer species, which set the lower limits of many prey species, are not vertically restricted to the same extent. As a result, many prey species which have a vertical refuge from predation on the outer coast do not enjoy such an advantage in Puget Sound. Many species which could otherwise survive in the low intertidal on physically stressful shores are locally extirpated by their predators. This conceptual model, backed with experimental evidence, provides a mechanistic explanation for the diversity gradient in the Northwest Straits. As such, the model provides a framework on which to base predictions about biological responses to future perturbations such as climate change and species invasions.

Marine Riparian: Assessment of Riparian Functions in Marine Ecosystems

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The marine nearshore, and estuaries in particular, provide some of the most productive and economically important ecosystems in the world. Despite being resource-rich and economically important ecosystems, the structure, functions and processes that form and maintain habitat in nearshore environments are not well understood. Of the many habitat elements comprising the nearshore, perhaps the least understood and most unappreciated, in terms of critical functions, is the riparian zone. Freshwater riparian areas have been studied intensively in recent years because of their critical habitat functions relative to healthy stream ecosystems. Although marine riparian areas have not been subject to the same level of scientific investigation, evidence is mounting that riparian areas serve similar functions regardless of the salinity of the water bodies they border. In this paper we provide a review of riparian functions as they relate to the marine environment, using the most commonly reviewed freshwater riparian function topics as a template. The functions and values reviewed for this paper include: Water quality, soil stability, sediment control, wildlife habitat, microclimate, organic/nutrient input, source of fish prey, habitat structure and LWD, shade, human health and safety, and aesthetics. Furthermore, we provide a review and discussion of the regulatory framework and management issues surrounding shoreline and resource management. We place a particular emphasis and focus on the Puget Sound nearshore due to the recent Endangered Species Act listings of several salmonids and the loss of habitat and ecosystem functions resulting from burgeoning human population growth and development practices in the Puget Sound region.

SESSION 1C: PUGET SOUND/GEORGIA BASIN WATER QUALITY, ROOM 402-403

Recent Studies of the Overturning Circulation in Hood Canal

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Washington State Department of Ecology

During the past three years, there have been several hydrographic surveys of Hood Canal as part of the PRISM program and a focused study by the DOE. The anthropogenic chlorofluorocarbons were measured on a subset of these surveys. Since these compounds are conservative below the pycnocline, their distributions can be used to estimate the average flushing time in the deep basin between surveys. These flushing rates can be applied to the distributions of other compounds (e.g. dissolved oxygen and nutrients) to estimate the rates at which these compounds are consumed or regenerated in the lower layer of Hood Canal.

The flushing rates ranged from 800 to 3500 $m^3 s^{-1}$ into southern Hood Canal. These values compared favorably with those calculated from the Cokelet-Stewart reflux model. An integration of the oxygen utilization rate within this deep layer supplies an estimate of the productivity of the overlying waters which is consistent with the ^{14}C primary productivity measurements.

Several other scientific investigations have resulted from these surveys. One interesting feature, which appears to be an annual occurrence, is an ammonium concentration maximum at the bottom located on the Hood Canal sill. This plume is strongest is the summer and disappears during winter.

Investigation of the Mean Flow in a Complex Multi-connected Estuary: South Puget Sound

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The Budd Inlet scientific study of 1996-97 showed that although variations in the freshwater inflow from the Deschutes River/Capitol Lake at the far-south terminus of Puget Sound varied six-fold (from 5 m^3/s in summer to 32 m^3/s in winter), the mean flow at the mouth of Budd Inlet merely doubled (200 to 400 m^3/s). This implied a baseline net transport, which was largely attributed to tidal as opposed to buoyancy forcing.

In the farfield, drift card releases suggested an H-like pattern in the mean flow where water from Totten Inlet exchanged with Pickering Passage and water from Eld and Budd Inlets exchanged through Dana Passage. The Environmental Fluid Dynamics Code-based South Puget Sound Area Model (SPASM) covers a larger area than the original Budd Inlet model. We use this model to explain and quantify seasonal combinations of tidal mixing, freshwater inflow, and to wind that give rise to the observed patterns.

The transport of water into and out of cross-sections of South Sound as computed from historical current meter measurements are compared with SPASM transports. Though South Sound contains a secondary fraction of Puget Sound's overall volume of water, it is unexpectedly active having transports comparable to that found in the much larger Main Basin off Seattle.

The Oceanic Remote Chemical/Optical Analyzer (ORCA): An Autonomous Profiler for Puget Sound

John Dunne, Steven Emerson and Allan Devol
University of Washington

We have developed an autonomous, moored profiler called the Oceanic Remote Chemical/optical Analyzer (ORCA) that senses a variety of chemical and optical properties. The purpose of this mooring is to monitor water quality in south Puget Sound - a mostly undeveloped area that is predicted to undergo extensive urbanization and is potentially at risk to eutrophication. ORCA has three main components: 1) a three-point moored ATLAS toroidal float 2) a profiling assembly on the float with computer, winch, cellular system, meteorological sensors (wind, temperature, humidity, irradiance), solar panels and batteries and 3) an underwater sensor package at the end of a hydro-wire with Seabird CTD profiler, YSI dissolved oxygen electrode, Wetlabs transmissometer and Wetlabs Chlorophyll fluorometer. At regular sampling intervals, ORCA profiles the water column using the winch driven by pressure information from the CTD. The data is recorded on the computer and transmitted back to the lab automatically via cellular communications to a host computer. Data is presented from the spring and summer of 2000 from a preliminary deployment in Carr Inlet. The data set reveals the extremely variability that exists on the day to week time scale in this estuarine system.

Estimating Loads of Nutrients, Bacteria, DO and TSS from 71 Watersheds Tributary to South Puget Sound

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Washington State Department of Ecology

The Washington State Department of Ecology has undertaken SPASM, a multi-year research project, to understand the behavior of south Puget Sound under current and future conditions based on water quality monitoring and hydrodynamic and water quality modeling. This paper describes efforts to produce daily time series of flows and loads from discrete watershed inflow points required by the three-dimensional EFDC model.

Detailed hydrologic modeling of each catchment would require tremendous resources. However, approximately 89 percent of the land area in the model domain has water quality monitoring data available[1]. A multiple-regression model[2] was developed that uses available site-specific water quality data to estimate daily parameter concentrations. The approach provides daily time series of parameter concentrations and calculated loads for the parameters of interest: nitrite/nitrate, ammonia, organic nitrogen, orthophosphate, organic phosphorus, total phosphorus, fecal coliform bacteria, total suspended solids, dissolved oxygen, oxygen demand and organic carbon.

We will summarize the regression approach, including assumptions and limitations, and present annual load estimates for 71 tributary watersheds. In addition, we will discuss the seasonal variations in loads and compare watershed loads by region as well as across individual watersheds.

[1] Programs conducted by Washington State Department of Ecology, U.S. Geological Survey, Thurston County, LOTT/Budd Inlet Study, and Bremerton-Kitsap County Health District.
2 Cohn, T.A., D.L. Caulder, E.J. Gilroy, L.D. Zynjuk, and R.M. Summers. 1992. The validity of a simple statistical model for estimating fluvial constituent loads—and empirical study involving nutrient loads entering Chesapeake Bay. *Water Resources Research*, v. 28, no. 9, p. 2353-2363; Cohn, T.A., L.L. DeLong, E.J. Gilroy, R.M. Hirsch, and D.K. Wells. 1989. Estimating constituent loads. *Water Resources Research*, v. 25, no. 5, p. 937-942.

Status and Trends of Fecal Coliform Bacteria in Shellfish Growing Areas in Puget Sound and the Straits of Juan de Fuca and Georgia

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Washington State Department of Health

The Washington State Department of Health (DOH) monitors fecal bacteria in shellfish growing areas throughout Washington State using a systematic random sampling strategy. Statistics (geometric means and ninetieth percentiles) are calculated from fecal coliform data annually to determine status and trends as part of the Puget Sound Ambient Monitoring Program (PSAMP). Analyses are currently underway for 19 "Core" areas (analyzed annually) located throughout Puget Sound and the Strait of Georgia, and 25 "Rotational" areas (analyzed every three years) in Hood Canal, Admiralty Inlet and Main Basin Puget Sound. Analyses cover the period through March 2000. Status and trends in fecal pollution will be reported for these areas. The relationship of trends in several growing areas with remedial activities in upland watersheds will be discussed.

SESSION 2A: FISH ECOLOGY AND BIOLOGY, ROOM 407-409

Nearshore Beach Seining for Juvenile Chinook *(Oncorhynchus tshawytscha)* and Other Salmonids in King County Intertidal and Shallow Subtidal Zones

Bill Mavros and Jim Brennan
King County Department of Natural Resources

The recent Endangered Species Act listing of Puget Sound chinook has prompted a number of actions to learn more about salmon life history and the impacts associated with habitat alterations. Although it is generally believed that juvenile chinook are ubiquitous in the nearshore, one of the critical gaps in our understanding of salmon life history is the utilization and importance of nearshore habitat. The estuarine environment is an important transition and nursery area for juvenile chinook and other salmonids. Limited sampling efforts in Puget Sound indicate that juvenile salmon are dependent upon the intertidal and shallow subtidal for feeding and refuge. However, the data that describe timing and distribution of juvenile salmonids in the nearshore is extremely limited, or nonexistant for most areas. In order to have a better understanding of salmonid distribution and timing, King County has implemented a pilot study that concentrated on sampling logistics, presence/absence of juvenile chinook in the nearshore environment, and development of a nearshore species composition database. Beach seining was conducted weekly at six locations throughout the study area from June 5 to August 16, 2000. Preselected locations were sampled with a 1m X 30m beach seine, deployed off of the beach by hand, at various tidal elevations during daylight hours. Chinook smolts were captured at all locations sampled and were the most

abundant salmonid species encountered. Coho sockeye, chum, steelhead and cutthroat trout juveniles and other marine species were also captured. Additional data on species composition, diet, growth, tidal influence and other factors are currently being analyzed and results will be presented. In addition, pilot study results will be used in the development of future sampling efforts planned for 2001 and beyond.

Trawl Metrics for Bottomfish and Epibenthic Marine Invertebrates as a Measure of Environmental Stress and Recovery

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The purpose of the biocriteria effort is to incorporate biotic measures of ecological structure and function derived from multiple biological assemblages into a broad-based index using natural reference conditions as benchmarks--the biocriteria. By linking the assessment and cleanup of environmental degradation to a biological index, the goal is to make the process not only much more *meaningful*—both socially and ecologically—but also much more *economical*.

This talk will focus on the five-year development of trawl metrics derived from sampling contaminated hotspots and comparing these areas to multiple reference areas of the same physical parameters. An objective evaluation of the usefulness of metrics derived from live-sampling the demersal fauna will be presented.

Comparisons analyzed for this study include

- Test site vs. reference site
- Nearfield vs. farfield
- Interannual variation
- Short-term variation

Spawning Season and Habitat of Olympic Outer Coast Surf Smelt *(Hypomesus pretiosus pretiosus)*

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National Park Service, Olympic National Park

Surf smelt occur on the Olympic outer coast and support an active recreational fishery. The coastal surf smelt population is thought to differ in its life-history from Puget Sound populations, however very little is known about the coastal surf smelt population biology and habitat use. The work presented here summarizes four years of spawning habitat monitoring at Rialto Beach in Olympic National Park. On a monthly basis, gravels were sampled from study transects and analyzed for gravel size composition and smelt eggs. Study results on spawning season and the relationship between egg deposition and gravel size show that surf smelt breeding season and habitat requirements differ from Puget Sound populations. Habitat use is likely affected by substantially greater wave action representative of the outer coast. Results from this study contribute to the understanding of surf smelt population biology and will result in more effective fishery management.

Effects of Shading Upland Vegetation on Egg Survival for Summer-Spawning Surf Smelt (Hypomesus) on Upper Intertidal Beaches in Puget Sound, Washington

Daniel E. Penttila
Washington State Department of Fish and Wildlife

The surf smelt, *Hypomesus,* is a common and ecologically important forage fish throughout Puget Sound. The species is nearly unique in using upper intertidal sand-gravel beaches for spawn deposition/incubation. Current habitat management regulations protect all known spawning substrate sites from physical destruction. Although it had been commonly observed that shaded smelt spawn was in better condition than sun-exposed spawn, the habitat value of an intact "marine riparian zone" of shading vegetation had not been objectively documented. WDFW summer surf smelt spawn survey records were examined for fortuitous pairings of "shaded" and "unshaded" spawn samples collected at otherwise similar spawn densities, ages and beach compass orientations. A statistical comparison of 37 such pairs found a significant difference in the mean percent dead eggs in samples from shaded versus unshaded sites, 36 percent to 60 percent respectively ($t_{(0.05(2)36)}=9.659$, null hypothesis of zero difference rejected). Thus it appears that summer surf smelt spawn survival is enhanced by a buffer of mature shading trees along the local supralittoral zone. Shoreline management plans should stipulate preservation or re-establishment of such buffers to aid in the conservation of summer-spawning Puget Sound surf smelt stocks.

SESSION 2B: TOXIC CONTAMINANTS IN THE PUGET SOUND/GEORGIA BASIN, ROOM 405-406

The Fraser River is Getting Cleaner: Will it Continue to Improve?

Colin Gray and Taina Tuominen
Environment Canada

Contaminant concentrations in sediments, fish and wildlife of the Fraser River declined significantly over the last decade. This was particularly true for dioxins, furans, chlorophenols, PCBs, and organochlorine pesticides. While fish and wildlife were still showing biochemical signs of contaminant exposure at these lower concentrations, indices of population health were not correlated with contaminant levels. This situation, however, may be reversed in the future because urban and agricultural non-point sources will increase with the rapidly expanding human population. There is also concern that levels of PCBs, DDT, toxaphene and other atmospherically transported pollutants in fish could increase if climate warming causes glaciers to release accumulated contaminants. Because loading from both of these sources is likely to continue, concentrations of some contaminants are not likely to decline further and others may increase. Increasing the effectiveness of non-point source controls in urban and farming areas may be required to keep concentrations below levels that would adversely affect biota.

Using Caged Mussels to Characterize Exposure from Point and Nonpoint Stressors in the Cherry Point Reach: The Value of *In-situ* Monitoring

Michael H. Salazar and Sandra M. Salazar
Applied Biomonitoring

Caged mussels *(Mytilus galloprovincialis)* were used as part of an integrated ecological risk assessment being conducted by the Washington State Department of Natural Resources to evaluate the potential causes of declining herring stocks from the Cherry Point Reach, WA. The caged mussel study had the following objectives: 1) Quantify potential chemical exposure of PAHs to herring eggs through mussel bioaccumulation; 2) Quantify potential associated effects through mussel growth metrics; 3) Quantify potential stress associated with temperature; and 4) Differentiate between point- and non-point stressors. Approximately 2300 mussels were transplanted to 12 stations in 1998, 44 stations in 1999, and 42 stations in 2000. Maximum concentrations of total PAHs in mussel tissues were similar in the 1998 and 1999 studies and approached concentrations associated with genotoxicity and developmental effects in previous studies conducted in Alaska as part of the *Exxon Valdez* oil spill. High temperatures could have been a significant stressor in 1998, the El Nino year. PAH fingerprinting and temperature changes during tidal cycles were used to differentiate between point- and non-point stressors. Most of these results could not have been achieved without the use of in-situ monitoring. A summary of results from 1998, 1999, and 2000 will be presented.

Toxic Contaminants in Pacific Herring (*Clupea pallasi*) from Puget Sound, Washington

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The Puget Sound Ambient Monitoring Program has monitored spatial and temporal trends of toxic contaminants in Puget Sound fishes from 1989 to the present. A pilot study on the feasibility of adopting Pacific herring (*Clupea harengus*) as an additional indicator species was conducted in 1995, and regular monitoring of herring begun in 1999. Pilot sampling of toxic contaminants in herring eggs was also begun. We have focused on two classes of toxic contaminants that accumulate in fish tissues, (polychlorinated biphenyls (PCBs), and pesticides (DDT, its metabolites, and hexachlorobenzene (HCB)), and one class that does not accumulate in fish tissues (polycyclic aromatic hydrocarbons (PAHs)). PCBs and pesticides were measured as concentrations from composites of whole fish. Recent exposure to PAHs was estimated from composites of fish bile, by measuring concentration of PAH-metabolites known as Fluorescing Aromatic Compounds (FACs). We also measured PAH concentrations in eggs-recently- laid by two distinct spawning stocks in Puget Sound, one near an oil refinery and one away from suspected oil sources.

Total PCBs in whole herring bodies in two Central/South Puget Sound locations ranged from 125 to 350 µg/kg, and were significantly greater than three northern locations (all less than 125 µg/kg). ppDDE comprised the bulk of the body burden of DDT and DDT-metabolite compounds in herring, with the greatest concentrations observed from the central Sound station (40 to 175 µg/kg. Herring from all other locations had concentrations less than 40 µg/kg. HCB was detected often, but in low concentrations (<1.8 µg/kg).

Biliary FACs (metabolites of benzo-a-pyrene, naphthalene, and phenanthrene) were significantly greater in herring from a central Sound location than northern and

a southern Sound locations. We observed no correlation between FAC concentration and biliary protein.

PAH and PAH-homologue compounds were not detected from herring eggs laid by the Port Gamble spawning stock at two locations (away from an oil refinery), however those eggs were only one-day-old. Eggs laid by the Cherry Point spawning stock at the three sites (near an oil refinery) were 7 to 8 days old, which confounded valid comparison with the Port Gamble egg samples. Eggs from two of the three Cherry Point sites had detected PAHs (dibenzothiophene, acenaphthene, naphthalene, 2-methylnaphthalene, and C-1 naphthalenes) ranging in concentration from 1.0 to 3.5 µg/kg (wet wt.) PPresence of some of these compounds is consistent with exposure to Alaska north slope crude oil, (which is refined nearby) however, concentrations were below a published lowest observable effects concentration (LOEC).

Implications For Reproductive Health in Rockfish from Puget Sound Exposed to Polychlorinated Biphenyls

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Washington State Department of Fish and Wildlife
Dan Lomax and Lyndal Johnson
Northwest Fisheries Science Center

Rockfish (*Sebastes* spp) are long-lived demersal predators that occur throughout Puget Sound, usually associated with rocky substrate. Because of their longevity, high trophic position and proximity to the seafloor, they can accumulate relatively high levels of polychlorinated biphenyls (PCBs). The Puget Sound Ambient Monitoring Program has monitored the presence and severity of contaminants, including PCBs, in 3 *Sebastes* species in Puget Sound from 1989 to the present. These species have been petitioned for protection under the Endangered Species Act, and specimens we sampled from urban or industrialized areas in Puget Sound have exhibited the highest concentrations of PCBs observed in any PSAMP-species.

We observed the greatest concentration of PCBs in male rockfish from urban areas like Elliott Bay and Sinclair Inlet (from 50 to 613 µg/kg muscle), and concentrations increased with fish age for males. Conversely, we observed relatively low [PCB] in female rockfish from the same locations (19 to 231 µg/kg muscle), and no relationship between fish age and [PCB] for females. These concentrations greatly exceed those that have been shown to cause impairment of reproduction in other species.

The patterns we observed have prompted further research into possible negative reproductive effects from this exposure. Using two estimates of toxicopathic effect, we compared rockfish sampled from Elliott Bay with fish from an uncontaminated reference area. (1) The presence of vitellogenin (a protein associated with egg production) in blood of males may indicate exposure to a contaminant that mimics the function of the female reproductive hormone, -estradiol. If an estradiol-mimic (e.g., certain PCB congeners) is present in males, it can trigger the production of vitellogenin, causing disruption in normal reproductive physiology. (2) Deformities in rockfish larvae may indicate exposure of progeny to PCBs via maternal transfer of the contaminant. Results from these comparisons are summarized in this paper.

SESSION 2C: CLIMATE-RELATED EFFECTS, ROOM 402-403

Effects of Climate Variability on Marine Water Properties and Phytoplankton Production

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Local weather patterns of the Pacific Northwest have been shown to respond to modes of climate variation such as El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), yet impacts of climate variation on the marine ecosystem are less understood. With regard to marine waters, this is in part because climate variation can have conflicting influences on basic physical and chemical water properties. For instance, more effective upwelling and high river runoff can both be associated with La Niña or the wet/cold PDO phase, yet upwelling results in high salinity surface waters while runoff results in low salinity surface waters. Additionally, it is important to differentiate how much of the variation in Puget Sound water properties is from the variation in nearby Pacific Ocean water properties versus the variation of more local weather conditions. Patterns of water property variation over the last decade will be summarized.

With respect to marine water quality and support of higher trophic levels, important variables influenced by climate variation are dissolved oxygen concentration, nutrient availability, and stratification intensity. It is apparent that an important factor in climate regulation of these variables is upwelling strength. Upwelled waters are low in oxygen and high in both nutrients and salinity, thus

resulting in stratified, highly productive, but possibly hypoxic water masses. Studies in Willapa Bay show profound ENSO-associated differences in phytoplankton production that appear to be directly linked to climate-induced variation in oceanic properties and processes. To what degree this same pattern is found for Puget Sound waters will be discussed.

Climate Variability, Climate Change, and Sea Level Rise in Puget Sound: Possibilities for the Future

Douglas J. Canning
Washington State Department of Ecology

Since 1989 the Washington State Department of Ecology, Shorelands Program, has been studying the technical, policy, and practical implications of climate variability and climate change, especially sea level rise, for Washington's marine waters. In recent years Ecology's work has been carried out in concert with the University of Washington Climate Impacts Group, and the emphasis has shifted to include consideration of estuarine ecology issues.

During this decade we have learned much; and there yet remains much uncertainty. We know that the most likely scenario for future sea level rise is lower than a decade ago; but we also now know that the matter can be complicated by temporary sea level increases due to El Niño, thus complicating forecasts for coastal erosion or coastal flooding.
We suspect that there might be a climate nexus with the rapid spread of Cordgrass (*Spartina* sp.) since the 1980s, but the evidence is less than clear. There appears to be good evidence for a connection between the Pacific Decadal Oscillation and the Oyster Condition Index but we lack thorough, region-wide studies.

We know that most government agencies at all levels are reluctant to include a consideration of climate change in their land use and resource management planning, and that consideration short term climate variation such as El Niño fares little better.
This paper explores the certainties and uncertainties of climate variability and climate change for Washington's marine waters, and suggests areas of management concern and research needs.

The Influence of Climate Variation and Change on Structure and Processes in Nearshore Vegetated Communities of Puget Sound and Other Northwest Estuaries

Ronald M. Thom, Dana L. Woodruff and Susan L. Blanton
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The effects of climate change on coastal systems needs study because of the importance of these systems to fisheries resources and the vulnerability of these systems to climate variations. Doubling of the CO_2 could increase estuarine and coastal productivity, carbon transport among systems, and carbon export to the deep ocean. Increased temperature could also increase system respiration, increasing CO_2 release. We have been investigating the potential for variations in ocean temperature and carbon dioxide to affect nearshore vegetated communities in the Pacific Northwest. Experimental studies as well as long-term monitoring suggest that these communities can and will respond to climate changes and that alterations in their functions may impact fisheries resources. In addition, we have been examining how coastal systems might act as sinks for carbon, and how to monitor these sinks. Variability in the flux of carbon among coastal systems and loss to export and other potential large sinks is in need of study to resolve how these system might act in terms of a global carbon sink. Strategies for enhancing carbon sequestration, such as through restoration of degraded coastal wetland systems, should also be investigated.

Interdecadal Change in Deep Puget Sound Benthos

Frederic H. Nichols
U.S. Geological Survey

The benthos of central Puget Sound was quantitatively sampled twice yearly in most years between 1963 and 1992 to examine the concept of long-term stability in a deep- water (200m) community. The study showed that the most abundant species were consistently present over the 30-year period. However, measures of overall species composition (e.g., similarity, diversity) reveal a subtle, gradual change in the community. Among the changes is the surprisingly steady decline in abundance of the large burrowing echinoderm, *Brisaster latifrons*, and the increased abundance and biomass of species that are tolerant of organic enrichment. Despite the conspicuousness of these changes, there are no obvious environmental factors that readily explain the changes, although circumstantial evidence suggests climate, organic enrichment, and predator abundance as possible influences. The principle reasons for our inability to identify causes of long-term change in the Puget Sound benthos are: (a) expected but unexplainable natural

biological variability, and (b) inconsistent long-term monitoring of environmental variables. The study results highlight the need for maintaining consistency in long-term monitoring programs focused on evaluating key biological populations and biologically relevant environmental variables expected to be influenced by human-induced stressors or remediation of those stressors.

Puget Sound Climate and Marine Biota: What Have We Learned?

Robert Francis
University of Washington

SESSION 3A: CHARACTERIZING AND PROTECTING NEARSHORE HABITATS, ROOM 407-409

British Columbia ShoreZone Inventory and Classification System—A Systematic Approach to Characterize Coastal Habitats in the Pacific Northwest

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A biophysical shore zone mapping system has been developed as part of a coastal shoreline inventory program for the coastal zone of British Columbia. It is a systematic methodology for mapping the biophysical character of the shore zone. The system is descriptive, scale-independent, cost-effective, and has a variety of natural resource applications. There are two major components to system—physical and biological.

The physical component and its hierarchical framework are the foundation of the biophysical system. The shoreline is segmented into homogenous alongshore units. A number of physical attributes are used to describe the units and their across-shore components. The biological component uses the hierarchical physical framework for recording the bio-bands and species data. The system relies on oblique, low-tide aerial video imagery flown at spring low tides as the primary source of information.

Information provided by the system supports a number of coastal initiatives including shoreline habitat modeling, conservation and protection, Marine Protected area identification, marine ecological classifications, regional and site land use planning, tenures, research, monitoring and oil spill response. The system has recently been adopted and implemented in the State of Washington. Completion of the both countries inventory programs will result in a systematic coverage of biophysical shoreline information that extends from the Columbia River mouth to the Alaska border.

Spatial Patterns in Shoreline Habitats: Results from the ShoreZone Inventory of Washington State

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Shoreline habitats have recognized ecological and management importance. In order to characterize broad scale patterns in Washington state's shoreline habitats, The Nearshore Habitat Program inventoried saltwater shorelines statewide between 1995 and 2000 using the ShoreZone Mapping System. The resulting GIS data set characterizes important physical, biotic and anthropogenic features. Inventory results show spatial patterns in features that are considered by many to be indicators of ecosystem health. Approximately 30 percent of the shoreline statewide has some kind of anthropogenic modification, ranging from more than 75 percent along highly developed eastern side of Central Basin to less than 5 percent along the relatively undeveloped rocky outer coast. There are more than 3,000 docks and approximately 30,000 recreational boating slips statewide. Eelgrass beds are present along 35 percent of shorelines. Canopy-forming kelp is present along 10 percent of the state's shorelines. The abundance and distribution of these features varies along environmental and human-use gradients. The state-wide inventory data set is available for use in regional research and planning projects.

Eelgrass Monitoring in Puget Sound: Overview of the Submerged Vegetation Monitoring Project

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Eelgrass *(Zostera marina)* is monitored in many regions as an indicator of nearshore habitat quality by comparing maps of resource abundance and distribution over time. In Puget Sound, there are environmental and scale-related barriers to using traditional systematic mapping methods for monitoring eelgrass. The study area is extensive (almost 4000 km of shoreline), and it is difficult to survey this subtidal species that can grow to a depth of *30 ft MLLW with traditional methods (divers, aerial photography, acoustic techniques). In summer 2000, the DNR initiated the Submerged Vegetation Monitoring Project as a nearshore habitat component of the Puget Sound Ambient Monitoring Program. The four goals of this project are to: (1) capture temporal trends in eelgrass abundance and distribution in Puget Sound; (2) summarize temporal trends over Puget Sound and subareas; (3) monitor vegetation parameters that are strong indicators of eelgrass extent and quality; and (4) link stressors to abundance and distribution. Six "core" sites will be sampled each year, and the remainder of Puget Sound will be sampled using rotational random sampling with partial replacement. This sampling plan addresses the two conflicting goals of sampling for status over large spatial areas (inventory) and capturing temporal trends (monitoring).

Mitigating Impacts of Overwater Floats on Eelgrass *Zostera marina* in Puget Sound, Washington

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The effects of using light-permeable deck grating on residential floats constructed over eelgrass (Zostera marina) was examined in the northern Puget Sound region of Washington to test the hypothesis that light permeable deck grating, inserted within the surface of a residential float would prevent loss of eelgrass underneath and adjacent to the float. Eelgrass shoot densities prior to construction of floats were compared to densities following construction at 9 sites which included 10 floats (one float had two parts that were tested separately). Each float was monitored for three years post-construction from 1991 to 1999. With up to 50 percent of the deck grated, a decline in eelgrass shoot densities was detected under four floats using ANOVA and under 6 floats using a linear regression approach. Adjacent to floats, a decline in eelgrass densities was only detected at one site. Our research suggests that grating up to 50 percent of the float deck was not by itself adequate to ensure “no net loss” of eelgrass.

We evaluated the effects of 20 attributes associated with the structure (e.g., size of vessel moored) and the surrounding landscape (e.g., density of the eelgrass and height of the float over the eelgrass) on changes in eelgrass density. There was no clear relationship between the overall number of positive or negative attributes and changes in eelgrass shoot density under floats. Rather, our results suggested that compass orientation of the float and seasonal removal of the float (i.e., removing the float during some months of the year) had an important influence on changes in eelgrass density under the float. Presently, the only way to ensure that a float will not impact eelgrass is to not build the float or to avoid sites with eelgrass. Grating >50 percent of the deck surface in combination with floats oriented N/S and/or seasonally removed may successfully avoid impacting eelgrass density. Further research is needed to better define how to mitigate impacts of floats on eelgrass. We recommend that further studies focus on testing how the interaction between float grating (>50 percent), float orientation and float seasonality can be used to avoid impacts to eelgrass.

SESSION 3B: MARINE MAMMALS AND BIRDS, ROOM 405-406

Marine Mammal Research Along the Northern Coast of Washington

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The National Marine Mammal Laboratory in cooperation with the Makah Indian Tribe, Washington State Department of Fish and Wildlife and other agencies has conducted research on marine mammals along the northern Washington coast for several decades. Research has focused on assessments of marine mammal species both inshore and offshore to determine abundance, distribution, seasonal usage, food habits and level of fishery interactions. Specific studies have been conducted on harbor porpoise, *Phocoena phocoena*, Gray whales, *Eschrichtius robustus*, Harbor seals, *Phoca vitulina*, Steller sea lions, *Eumetopias jubatus*, and California sea lions, *Zalophus californianus* on the northern coast in the area included within the Olympic Coast National Marine Sanctuary (OCNMS). The OCNMS contains a diverse and rich feeding habitat for these species and also provides resting and hauling sites for the pinnipeds on offshore rocks and islands. The species of marine mammals considered here are all considered healthy in respect to their population levels within the area. Approximate estimates of peak abundance for the species within the OCNMS are; harbor seals->5,000, Steller sea lions-1,200, California sea lions->5,000, Harbor porpoise->3,000, and Gray whales-200-300 (during migration peaks). Although some of these species are subject to either Tribal harvests or fishery related mortality the levels are not considered to be excessive or likely to cause any immediate harm to the local populations. Of more immediate concern is to determine the relationship between these species and their primary prey in the region, especially prey species which are listed under the Endangered Species Act, depleted, or heavily exploited by commercial fisheries.

The Impending Sea Otter Crisis in Washington: Ecological Effects and Political Implications

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Sea otters (*Enhydra lutris* [L.]) currently range from Kalaloch to Sekiu. The population numbers about 600 individuals and is growing more than 10 percent per year. Since 1995 the population has been expanding eastward into the Strait of Juan de Fuca during winters. Reliable recent extralimital sightings have been made at San Juan and Whidbey Islands and in southern Puget Sound. Sea otters are widely known for controlling populations of grazing invertebrates, thereby enhancing the diversity and productivity of coastal ecosystems, and for negative impacts on fisheries for sea urchins, Dungeness crabs, abalones, and clams. We review data on likely interactions of sea otters and coastal ecosystems in the eastern Strait of Juan de Fuca as the sea otter population expands. We find significant potential for negative effects on fisheries for Dungeness crabs, sea urchins, and hardshell clams, but little potential for enhancement of the biodiversity or productivity of ecosystems. The growing sea otter population provides an urgent incentive for agencies to establish management goals and begin planning for implementation. The decision process will be contentious, will involve strongly expressed inputs from stakeholders with conflicting values, and will challenge the political skills and resolve of relevant authorities.

Breeding Phenology and Diet of Caspian Terns in Southern Puget Sound, Washington

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Washington State Department of Fish and Wildlife

Caspian Terns, *Sterna caspia*, are large gull-like birds that feed exclusively on small forage fish. In recent years, their population size has exploded to more than 25,000 in the Pacific Northwest where annually they eat many millions of federally protected juvenile salmonids in the Columbia River and elsewhere. Effective management of salmon requires balancing the negative impacts on terns

of certain salmon management activities against the benefits of these activities to salmon. Three steps toward this goal are (1) determining what percentage of the diet is composed of salmonids at each tern breeding colony, (2) estimating tern abundance and productivity at each colony, and (3) identifying potential breeding sites at which the impact on salmonids might be reduced. Caspian Terns have been breeding at the former ASARCO smelter site along Commencement Bay in southern Puget Sound since at least 1997. In summer 2000, a maximum of 2000 to 2500 adults occupied the ASARCO site, many of which successfully fledged young. Adults appear to feed more salmon to their young than they eat themselves. Overall, more than half their diet is composed of salmonids, the other major prey items being surf smelt, Pacific herring and shiner perch.

Herons and Eagles and Crows, Oh My! Causes of Abandonments at Great Blue Heron Colonies

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An increase in colony abandonments at many heronries throughout Puget Sound and the Strait of Georgia has re-focused efforts again on the issue of disturbance, as well as locating and protecting alternate nesting sites for herons. The increase in bald eagles and crow populations has resulted in opportunistic interaction between the three species in which heron egg predation by crows occurs during early season incursions into heron colonies by eagles. Complete lack of chick production has led to concerns about possible population decline. A new project has been funded to use the aerial PSAMP monitoring of heron foraging sites during their peak use of eelgrass beds in June as method to document population independent of nesting colonies.

Heron colonies and foraging areas within the Urban Growth Boundaries in Puget Sound continue to face development pressures. Detailed colony surveys were performed during the summer of 2000 and foraging areas in the winter. Monitoring of large colonies at Renton, Kenmore, and Issaquah has resulted in questions about the role that prey abundance plays in colony success and abandonment at freshwater colonies. New studies on disturbance and productivity will also be presented.

SESSION 3C: WATERSHED AND ESTUARINE ASSESSMENT AND PLANNING, ROOM 402-403

The Need for Process-driven, Watershed-based Wetland Restoration

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The continued decline in the health of aquatic species and ecosystems indicates that something is dramatically wrong with our current approach to resource management in the Pacific Northwest. Causes for this lack of success fall into two general areas. First, very complex ecosystems have been over-simplified or dissected into individual parts to facilitate regulation and management. Second, existing regulations and recovery efforts typically focus on structural components at a site scale. Considerable evidence suggests that process-driven, watershed-based tools that look at multiple spatial and temporal scales need to be developed to provide the conceptual framework for organizing and coordinating management and recovery actions at the site scale. In 1994, Washington State Department of Ecology initiated a landscape-scale wetland restoration program to meet an objective of the Puget Sound Water Quality Management Plan. In 1998, an interdisciplinary technical team was assembled to build on this work in concert with emerging concepts in the literature to develop tools that help recover threatened and endangered salmon runs, improve degraded water quality, and address causes of increased peak flows and declining stream baseflow. This paper presents insights gained during development and initial implementation of these landscape-scale process-based assessment efforts.

The Snohomish Estuary Salmon Overlay– A Tool For Regional Habitat Restoration Planning

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The Snohomish Estuary Wetland Integration Plan (SEWIP) model was originally developed by an interagency expert panel. This model used the indicator value assessment approach to rate quality of tidal marine and estuarine areas for various natural resource functions

including salmonid habitat (migration, feeding, saltwater acclimation, health, predation). SEWIP also used the model to rate habitat enhancement, restoration, and mitigation potential and to identify high priority restoration projects in the study area. SEWIP was used to assess impacts and mitigation needs for a 7-acre nearshore fill in Everett Harbor and as an aid to design of a tidal restoration project. The SEWIP model has now been revised by an expert panel of agency and tribal representatives to ensure that the model structure and output reflect the best available science related to how salmonids use habitat. Tidal areas within the Snohomish Estuary and Port Gardner were scored using the revised salmonid model to define the baseline or existing area and quality of habitat. Actions that would be necessary to achieve a 15 percent increase in habitat as rated by the model were identified and ranked. This goal was found to be achievable at reasonable economic cost. Other model applications will be discussed.

A New Method for Identifying and Prioritizing Areas for Habitat Restoration in Puget Sound's Rural Estuaries

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People for Puget Sound
Curtis Tanner
U.S. Fish and Wildlife Service

Spurred by proposed Endangered Species Act listings of Puget Sound salmon and other marine species, we developed a GIS site selection tool to identify and prioritize restoration and conservation targets throughout the Sound. For the Restoration Blueprints, we used ARC GRID and ArcView to create a coincidence model based on historic tidal influence, seasonal and tidal flooding, hydrologic zones, ecological sustainability, land use and land cover, and parcel density. These criteria are based on principles of landscape ecology and ease of restoration. Results of the model assigned highest priorities to those areas in the lower delta that are adjacent to major river distributaries and held in public ownership. This analysis for the Skagit Estuary could be applied to any rural delta in the Puget Sound/Georgia basin.

A Comprehensive Assessment of the Central Puget Sound (King County) Nearshore Ecosystem: Historic Changes, Data Gaps, and Pending Threats

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Jim Brennan
King County Department of Natural Resources
Ronald M. Thom, Marty Miller, Dana Woodruff, Amy Borde, Susan Blanton, and John Southard
Battelle Marine Sciences Laboratory

We are currently preparing a reconnaissance assessment document on nearshore resources in King County's Watershed Resource Inventory Areas 8 and 9 (comprising most of the coastline between Tacoma and Everett), as part of Puget Sound's region-wide salmon recovery planning effort. The habitats and processes of the nearshore zone, defined as the area between the riparian zone and the lower photic zone (-30 m MLLW), are of critical importance to a wide variety of marine species, and remain one of the least studied links in regional salmonid life histories. Despite numerous existing studies and data sets on a variety of nearshore topics, there has been no comprehensive summary of this information to date. Our report synopsizes, and identifies major gaps in, the existing nearshore literature on ecological conditions, habitats, processes, and resources. This specifically includes: major habitat distributions, shoreline conditions (modifications), primary productivity dynamics, food web interactions, nutrient dynamics and water quality, and salmonid, finfish, and shellfish distribution and use. Results from this State of the Nearshore document will serve to: 1. provide a basis for nearshore watershed planning and salmon recovery efforts; 2. identify data gaps and direction for future technical work; and 3. assist researchers, planners, and managers dealing with coastline issues in the region.

SESSION 3D: EFFECTS AND ECOLOGICAL INTERACTIONS OF CULTURED BIVALVES, ROOM 404

Ecological Interactions Associated with Cultured and Restored Bivalve Populations in Chesapeake Bay

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During the 20th century populations of the eastern oyster, *Crassostrea virginica*, declined dramatically in Chesapeake Bay. A growing body of evidence indicates that oysters were a keystone species in this system and that their demise has resulted in large-scale changes in the ecosystem. The loss of filtration by oysters and the biogenic habitat that they create are suspected of

increasing eutrophication, altering food webs and resulting in the decline of numerous reef-dependent fishes. Two recent activities in the Chesapeake Bay may offer the potential to reverse this trend and restore some of the role of shellfish in controlling phytoplankton dynamics and in providing habitat for other species. Active restoration efforts are underway to rebuild reefs and their associated populations, and aquaculture of both hard clams (*Mercenaria mercenaria*) and oysters is expanding rapidly. A number of studies are currently underway that are attempting to elucidate ecological interactions of these managed shellfish habitats within the surrounding landscape. Separate studies investigating the assemblages of organisms associated with experimental reef restoration projects and with oyster aquaculture floats have identified comparable assemblages associated with each. Coupled with estimates of filtration capabilities, these findings suggest that shellfish habitats could be managed to restore lost ecological functions in the bay.

Environmental Response to the Intensive Cultivation of Fish and Shellfish in the Pacific Northwest

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Aquatic Environmental Science Laboratory

Supplying the fish and shellfish necessary to feed the earth's burgeoning human population has placed an unsustainable strain on fish and shellfish resources all around the globe. Modern terrestrial agricultural has developed to the point where we raise the meat, vegetables and grains on a fraction of the available uplands. Despite over 50 years of hard work by Conservation Districts and the Natural Resources Conservation Service to reduce erosion, soil losses from upland agriculture in Washington State still averaged four to eleven tons of topsoil per year from each acre of cultivated land. These fertile soils are washed into our streams, rivers, lakes and estuaries. It takes decades to centuries for this material to work its way downstream to the ocean. This is one of the costs of a human population that is nearing six billion people. Similarly, the intensive cultivation of fish and shellfish also creates changes in local marine environments. The focus of this talk is on the environmental effects associated with shellfish culture. However, because much of my research focuses on the greater effects associated with fish culture, I will rely on that experience as well. Aquaculture effects are generally of four kinds. Structural effects create new types of habitat and generally increase the abundance and diversity of life around aquaculture facilities. Water column effects are created by the uptake of detritus, phytoplankton and oxygen - and the release of nutrients from large growing biomasses of fish and shellfish. Adverse effects on the water column have rarely been documented in association with aquaculture and they have not been observed in the Pacific Northwest. Benthic effects are created by the deposition of biological debris, including pseudofeces, feces and fouling organisms from raft culture of shellfish and feces from netpen culture of finfish. These physicochemical changes frequently lead to changes in benthic communities. In well flushed environments these biodeposits frequently lead to significant increases in both the diversity and abundance of benthic communities. In slowly circulating bodies of water, the rate of biodeposit accumulation can exceed the assimilative capacity of the sediments leading to excess biological oxygen demand, oxygen depletion, and the creation of excess sulfides. As organic loading increases, sediments may become dominated by what are called opportunistic organisms - generally annelids like *Capitella capitata*. In extreme cases sediments can become anaerobic, dapauperate and covered with white mats of Beggiatoa. However, unlike terrestrial agriculture, these effects have repeatedly been demonstrated to be ephemeral lasting from a few weeks following harvest to at most a few years in association with fish culture. Current studies in British Columbia are revealing the relationship between benthic communities and sediment concentrations of organic carbon, oxygen and total sulfides. These studies are demonstrating that benthic community changes can be predicted by evaluating the concentration of total sediment sulfides and the oxidation-reduction potential. Preliminary results suggest that total sulfide levels less than 800 micromoles are associated with biological amplification; concentrations of 1000 to 2000 micromoles with changes in community structure and domination by opportunistic organisms; and that benthic communities become increasingly depauperate at concentrations above 3,000 micromoles. These studies will be complete in May of 2001. It is my experience that the environmental effects associated with aquaculture are far shorter lived and more easily managed than the environmental risks associated with upland agriculture. To assist in managing the risks associated with mussel culture, I have recently completed work on a technical document supporting an environmental impact statement for raft culture of mussels. This work describes various methods for assessing the environmental response to intensive mussel culture and indicates that Totten Inlet, in South Puget Sound is currently at about ten percent of its bivalve carrying capacity. Furthermore, this work indicates that intensive bivalve culture tends to smooth out nutrient flows and phytoplankton production over a longer period each year. The sustainability of marine life depends very much on a healthy environment and on aquaculture's ability to satisfy much of humankind's demand for fish and shellfish - thereby taking pressure off wild stocks. The real question confronting those who care about marine resources is not whether or not we embrace aquaculture in the Pacific Northwest or push it offshore into third world countries. The important question is how do we manage aquaculture so that it remains a beneficial tool in our efforts to sustain all marine resources throughout the world.

The Role of Oyster Aquaculture as Habitat in West Coast Estuaries: A Review

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A review of several field studies suggests that oyster aquaculture practices have an influential role in structuring the benthic macro-invertebrate community in west coast estuaries. Oysters act as "bio-engineers" changing the structure of the substrate and creating habitat for other organisms. Macro-invertebrate communities are typically more diverse in intertidal ground culture oyster habitat as compared to other estuarine habitats, in particular intertidal mud and burrowing thalassinid shrimp dominated habitats. Oysters add structure for macro-algal, mussel and barnacle attachment which in turn provide protection and/or food for juvenile Dungeness crab, shore crabs *Hemigrapsus*, tube building gammarid amphipods such as *Amphithoe* and *Corophium*, caprellid amphipods, tanaids, and some annelids such as the scaleworm *Harmothoe*. Two other bio-engineers, the ghost shrimp *Neotrypaea californiensis* and the mud shrimp *Upogebia pugettensis*, dominate large portions of the intertidal in some west coast estuaries and compete for space with oysters and eelgrass. These thalassinid shrimp create a soft, highly burrowed habitat suitable for other burrowing organisms like the amphipods *Eohaustorius* and *Eobrolgus*, the polychaete *Mediomastus*, and some commensal organisms like the clam *Cryptomya*, but support fewer large filter feeders, less habitat for larger mobile crabs, and much lower species diversity than oyster habitat. Some proposed work aims to compare the functional role of oyster dominated habitat versus that dominated by eelgrass and open sand/mud dominated by thalassinid shrimp for the estuarine fish community, but to date, little has been done to estimate the effects of oyster aquaculture and farming practices at the larger estuarine ecosystem scale.

Shellfish Culture in the Estuary: Are Growing Shellfish and Estuarine Stewardship Compatible?

Jonathan P. Davis
Taylor Shellfish Farms

SESSION 4A: MARINE PROTECTED AREAS, ROOM 407-409

Criteria for Establishing and Monitoring No-take Refuges for Rockfishes and Other Rocky Reef Fishes in Puget Sound

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Washington State Department of Fish and Wildlife

Rockfish populations in Puget Sound have shown declines in size, abundance, and reproductive success since the mid-1970s to such an extent that they are being considered under the Endangered Species Act as threatened or endangered. Previous research has shown that rockfishes and lingcod living in no-take refuges are larger, more abundant, and have higher reproductive capacities than in comparable fished areas. These results and others factors have prompted many agencies and organizations to begin planning the creation of no-take refuges throughout Puget Sound to promote the recovery of depressed species and to insure ecosystem integrity. While general guidelines for the creation of no-take refuges exist, specific criteria for creating or monitoring the success of a refuge system for rockfishes and other reef species are lacking.

In recent years, the Washington State Department of Fish and Wildlife has undertaken a number of studies specifically aimed at determining reef fish stock abundance, habitat requirements, and responses to no-take refuges. The results from these studies provide the basis for establishing a refuge network and targets for network success. Pertinent results include maps of nearshore rocky reef habitats, preferred habitat characteristics, historical and refuge size frequencies of key fish species, and fish density observations from long-term refuges. These specific criteria are integrated with recent and published guidelines for rockfish and other refuges throughout the world into a planning scheme for a Puget Sound reef refuge system.

The Eye of Poseidon: Collecting, Organizing and Modeling with Geospatial Resource and Habitat Data to Help Identify Targets for Marine Protected Area Designation

Phil Bloch, Mike Sato, and Jacques White
People for Puget Sound

Over the last year, People for Puget Sound has collected and connected geospatial datasets for important habitats and marine species, bathymetric contours, public lands and marine parks, and local and cultural knowledge. Using the best data available, People for Puget Sound has worked with Canadian and American groups to map these factors as part of a Transboundary Geographic Information System. This Marine Resource Atlas is the foundation of a modeling tool designed and target and

define a system of Marine Protected Areas in the northern Sound and Straits. Identifying, collecting and compiling data for important marine habitats and species is the first step in creating a methodology for locating areas of biological importance. Defining nearshore and marine zones based on bathymetry creates two distinct sets of characterization and analysis. A preliminary list of key marine and nearshore habitats and species provide a simple set of site selection criteria. Early results from the site selection model will be presented.

Using Oceanographic Linkages to Guide Marine Protected Area Network Design

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Marine protected areas (MPAs) will be most effective when established as networks linked through larval dispersal. Larval import will provide new individuals to protected populations, and larval export will supply individuals to surrounding populations. Therefore, larval dispersal trajectories are one important element of network design.

We used drift cards to characterize larval transport by surface currents in the San Juan Archipelago (SJA) and Northwest Straits region of Washington state. 6400 cards were released from 16 sites within the SJA from April through September, 1999. Nearly 40 percent of these were recovered and reported to us. Throughout the region, cards tended to accumulate on a relatively small proportion of the total shoreline. For example, within the SJA, approximately 70 percent of the cards accumulated on only 15 percent of the shoreline. The spatial distribution of recoveries suggests that sites within the SJA are tightly linked with each other and with several other sites around the eastern basin of the Strait of Juan de Fuca. In particular, the southwest shore of Lopez Island, Dungeness Spit, the northwest shore of Whidbey Island, and the Victoria area all are likely to sustain high levels of larval import, indicating their potential importance in regional MPA network design.

Census of Lingcod Nesting Activity in the Edmonds Underwater Park

Kirby W. Johnson
Snohomish County Marine Resource Committee

Can useful data be collected by volunteers? The question may be partially answered by a continuing census of lingcod nest sites in the Edmonds Underwater Park. Volunteer divers conduct the census to document lingcod reproduction as an indicator of the overall health of the site.

Nearing 30 years old, the Edmonds Underwater Park is one of the oldest marine sanctuaries and is a unique environment in several ways. Habitat consists of many unusual artificial reef features in a lattice of concrete block and rope trails. It is somewhat isolated from natural lingcod habitat. The 27 acre park is also heavily used by recreational scuba divers.

Divers perform surveys using measuring sticks and slates to collect data on the egg masses and the guard fish during the nesting season. Numbered ID tags are used to locate and mark lingcod egg masses for repeat observation. Nest locations are mapped and data are entered on a spreadsheet. Photographic records have been made of many sites. The park typically provides more than 60 nest sites per season. Four years of survey results have been collected.

Among the observations is strong evidence of repeat usage of specific sites. There have also been several instances of repeat use of a site by individual guard fish identified by physical characteristics (scarring). Data has also been collected on predation of eggs, storm damage to egg masses, and stamina of the guard fish over the season. The surveys are evidence of the capability of a non-professional volunteer team to collect meaningful data.

SESSION 4B: SHORELINE MODIFICATIONS, ROOM 405-406

Shoreline Armoring of Puget Sound— A Habit We Just Can't Kick

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Thurston Regional Planning Council

In 1993 Thurston Regional Planning Council (TRPC) inventoried the Puget Sound shorelines within Thurston County. This initial effort resulted in a digital data base and a tabulation of shoreline armoring over time. Efforts were made to identify the type, location and date when bulkheads were installed using 1977 as the base year. The project documented the difficulty of accurately documenting these factors without the permit tracking system begun in 1984. A historical rate of bulkheading activity, both Countywide and by inlet was established. For Thurston County the length of armored shorelines more than doubled (110 percent increase) during the 1977-1992 time period.

In 1999 TRPC completed an update of this project and the results are surprising. Less than 100 feet of new marine shoreline has been armored in the last two years. Fewer permits are being issued and repairs are now including "footing" or bulkheads for bulkhead. Footing are becoming more common as beaches are being eroded. With all the bad news regarding near shore habitat loss, some good news is nice. What are the potential effects on the rest of Puget Sound given these trends? What techniques can be learned regarding bulkhead inventories? What successful local management strategies have been accomplished, without substantial changes to State Law?

Soft Shore Protection as an Alternative to Bulkheads–Projects and Monitoring

Jim Johannessen
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Traditional "hard" bulkheading has been the norm at Puget Sound and Northwest Straits shores until very recently, when "soft shore protection" alternatives have been encouraged by regulators and well-informed citizens. Soft shore protection locally entails the use of indigenous materials such as gravel, sand, logs, and root masses in designs that have some degree of flexibility, mimicking natural processes. Projects typically rebuild the high-tide beach to provide protection of property and homes and increase coastal sediment supply, the foundation of our sediment-starved coastal systems. Projects also have beneficial elements for nearshore habitats that include introduction of woody debris, shading, revegetation, and increased shoreline complexity. Projects have ranged from large beach restoration to enhancement of gravel and wood berms fronting single-family residences. A 900-foot long beach on Blakely Island in San Juan County was restored in early 1998 and the backshore area was extensively replanted. An 850 ft long enhanced beach that included a wide gravel berm and a replenished sandy backshore was constructed at a severely degraded Samish Island beach in 1997. Monitoring results are presented for 3 years for these 2 sites. Smaller Soft shore protection projects are also presented. Further work needs to be conducted to document and improve project performance and acceptance of soft shore protection. Rigorous assessment of project performance to include current beach surveys at a variety of old and newer projects is required.

"Bio-Structural" Erosion Control: Incorporating Vegetation in Engineering Designs

Elliott Menashe
Greenbelt Consulting

The conventional engineering approach to slope stabilization and erosion control usually relies solely on structural components. Vegetation is rarely included in engineering designs, though occasionally it is treated as incidental landscaping. Though the benefits of vegetation's role in erosion control are poorly understood within the engineering community; the value of vegetation in controlling erosion and reducing shallow mass wasting is well documented.

While engineered structures provide immediate stabilization and erosion abatement, they become progressively weaker over time and do not adapt to changing site conditions. Vegetation, though ineffective when first established, becomes progressively more effective, adaptable, and self-perpetuating over time. Vegetation also improves water quality, reduces storm water run-off, enhances wildlife and fisheries habitat, improves aesthetics, and reduces noxious weed establishment.

A "Bio-Structural" approach to erosion and slope stability problems; i.e., incorporating planned vegetational elements in engineering designs, can be less expensive, more effective, and more adaptable than purely structural solutions. Vegetation should be used in conjunction with geo-textiles and engineered structures whenever appropriate and practical.

Beach Nourishment On Puget Sound: A Review of Existing Projects and Potential Applications

Hugh Shipman
Washington State Department of Ecology

Coastal planners and resource managers increasingly consider beach nourishment a viable alternative to conventional shoreline armoring for addressing erosion on Puget Sound. Few projects have been well documented, however, and technical information on the geomorphology and engineering of gravel beaches is limited. In this project, we evaluated approximately thirty nourishment projects on Puget Sound through field investigation, interviews, analysis of historical conditions, and review of project records. We specifically looked at how the projects' geologic settings affected their design and success. We found that nourishment has been employed in highly diverse situations, from residential sites to industrial cleanup actions, and at many scales, from small pocket beaches to large beach feeding

projects. A majority consist of gravel beaches in public parks. Most occur on low-lying shorelines, whereas few have been constructed on bluff-backed beaches. Nourishment has been used for erosion control, recreational enhancement, mitigation for armoring, and as a component in biological enhancement efforts. We conclude that nourishment is an important tool in addressing shoreline problems on Puget Sound, but that effective application requires improved engineering and regulatory guidance, systematic monitoring, and increased knowledge of the geomorphologic processes acting on individual sites.

SESSION 4C: CONTAMINATED SEDIMENTS, ROOM 402-403

Spatial Extent of Sediment Contamination, Toxicity, and Associated Biological Effects in Puget Sound

E.R. Long
National Oceanic and Atmospheric Administration
M. Dutch, S. Aasen, C. Ricci, and K. Welch
Washington State Department of Ecology

Sediments were sampled at 300 locations within the greater Puget Sound region during 1997-1999 to quantify the spatial extent of chemical contamination, toxicity, and the relative abundance and diversity of the benthic infauna. Sampling and analyses were conducted in a joint effort of the Puget Sound Ambient Monitoring Program of the Department of Ecology and the National Status and Trends Program of the National Oceanic and Atmospheric Administration. Results showed that the samples in which sediment quality guidelines were exceeded, highly significant toxicity occurred, and in which the benthos were reduced in diversity and abundance represented less than 1 percent of the total survey area. Degraded conditions were mainly restricted to several urbanized bays, including portions of Elliott Bay and Commencement Bay. Broad expanses of the main basin of Puget Sound and most adjoining areas were not contaminated, not toxic, and supported an abundant and diverse benthic infauna. Toxicity data indicated conditions in Puget Sound were considerably better than in most marine bays and estuaries sampled elsewhere in the U.S. by NOAA.

Immunocompetence of Juvenile Chinook Salmon Following Exposure to Dietary PCBs: Implications for Regulatory Policy

Kathy L. Godtfredsen and D. Michael Johns
Windward Environmental LLC
Doug Hotchkiss
Port of Seattle
Matthew G. Luxon
Windward Environmental LLC
Roger C. Palm, Jr., and David B. Powell
ProFishent, Inc.

Protection of threatened Puget Sound chinook salmon is a goal we all share. With ProFishent, Inc., we conducted experiments to investigate whether PCBs in the exposure regime of the Lower Duwamish Waterway may cause immunosuppression effects among outmigrating chinook salmon. The results of these experiments are discussed in a parallel presentation.

The objective of this talk is to evaluate the implications of these results from a regulatory perspective. With the listing of Puget Sound chinook salmon under the Endangered Species Act (ESA), take of individuals is prohibited. To evaluate risk of harm, endpoints in addition to the traditional suite of growth, survival, and reproduction are attracting more attention and should be critically evaluated before use in regulatory programs. Some studies have suggested that immunosuppression impacts are possible as juvenile chinook migrate through the Lower Duwamish Waterway. Although the specific causative chemicals and threshold concentrations have not been identified, PCBs and PAH compounds have been mentioned as potential candidates. Results suggest that total PCB concentrations of 18 ppm dw in food, resulting in body burdens of approximately 1 ppm ww in fish, do not cause immunosuppression in juvenile chinook salmon. We will discuss the implications for Superfund, Natural Resource Damage Assessment, and ESA.

Evaluating the Effectiveness of Capping Mercury Contaminated Sediments at Eagle Harbor, Washington

R. Robert Zisette and Walter T. Trial, Jr.
Herrera Environmental Consultants
Melany Vorass
Washington State Department of Transportation
Clay Patmont
Anchor Environmental

Sediment remediation at a former shipbuilding yard in Eagle Harbor, Washington has been directed at the removal and disposal of “hotspot” sediments contaminated with mercury, as well as the construction of “thick” (1m) and “thin” (15cm) layer caps of clean sediment over less contaminated areas of the site. Monitoring of sediment quality has focused on surface

and suspended sediment, and on the colonization of the cap areas with marine organisms. Two years after construction, mercury concentrations in surface sediments (0-10cm) ranged from 0.015 to 0.550 mg/kg (dry weight) in the cap areas, which is less than the marine sediment cleanup level (0.59 mg/kg) and less than mercury concentrations observed in off-cap areas of the harbor (0.595 to 1.18 mg/kg). Monitoring of suspended sediments within the harbor, using sediment traps deployed over a 70-day period, revealed that mercury concentrations have decreased from a baseline (1990) concentration of 1.05 mg/kg to 0.387 mg/kg. Low tide surveys demonstrated that the cap areas have been successfully colonized by 51 invertebrate species with barnacles, amphipods, periwinkle snails, and polychaete worms being most abundant. These initial results indicate that capping of mercury-contaminated sediments at Eagle Harbor has been an effective remediation technique.

Siting a Confined Disposal and Treatment Facility Within a Regional Framework for Managing Contaminated Sediment: Lessons Learned And Remaining Challenges

Thomas Gries
Washington State Department of Ecology
Steve Babcock
John Dohrmann
Puget Sound Water Quality Action Team
Tim Goodman
Eric Johnson
Washington Public Ports Association
John Malek
U.S. Environmental Protection Agency
Stephen Martin
Fred Seavey
U.S. Fish and Wildlife Service

The need for a comprehensive sediment management program in the Puget Sound region was recognized more than 20 years ago. A cooperative program to effectively manage cleaner dredged material was established in 1988. Sediment management standards promulgated in 1991 define requirements for cleaning up contaminated sediment and controlling continued discharges. However, remediation of contaminated sites identified since 1996 has often been delayed because of inadequate regional confined disposal capacity.

Seven federal, state and quasi-public parties are now participating in a joint effort to site and build regional capacity to manage contaminated dredged material by a combination of beneficial uses, treatment and disposal. Thus far, challenges encountered in the multiuser disposal site or MUDS project include funding feasibility studies, reaching consensus on technical and policy issues, generating public interest prior to choosing preferred types of facilities and sites, and identifying a willing facility owner. Many of these challenges have been or are in the process of being resolved, but other significant hurdles remain. Key issues remaining include demonstrating a reliable flow of contaminated material, identifying methods to accelerate cleanup activities, determining the appropriateness of using public lands for aquatic disposal and evaluating the long-term safety and liability of products manufactured from sediment treatment processes.

The authors also describe the need to create a public entity with all the legal authorities needed to form a partnership with one or more private companies to develop confined disposal and treatment capacity. This MUDS authority will need to define the optimum partnership, secure adequate funding, obtain technical and policy assistance, generate legislative interest and public acceptance in order to select, design, build and permit a regional facility.

SESSION 4D: NATURAL HAZARDS, ROOM 404

Tsunamis in the Puget Sound Region: A New Program

S. Koshimura, H.O. Mofjeld, F.I. González, and V.V. Titov
National Oceanic and Atmospheric Administration

A program is underway to better understand and predict the tsunami threat in the Puget Sound Region. In the Strait of Juan de Fuca, tsunamis generated by earthquakes in the Cascadia Subduction Zone or propagating from distant Pacific sources represent the greatest threat. Within Puget Sound, dangerous tsunamis are more likely to be generated by local earthquakes and landslides. This work is being carried out at the Center for Tsunami Inundation Modeling Efforts, which is part of the Federal/State National Tsunami Hazard Mitigation Program.

The initial focus of the modeling in Puget Sound is the tsunami that was generated 1000-1100 years ago by an earthquake on the Seattle Fault. Paleotsunami evidence at West Point, Seattle, and Cultus Bay on Whidbey Island suggest the occurrence of this tsunami. Results from a high-resolution numerical model will be shown, indicating the areas around the Main Basin of Puget Sound that are most vulnerable to this type of tsunami. Future research will include the investigation of landslide-generated tsunamis and seismically generated seiching in lakes.

Post-glacial Influence of Lahars and Laharic Floods on the Landscape of the Puget Lowland, Washington—A Review of Selected Publications and Recent Discoveries

Patrick Pringle
Washington State Department of Natural Resources

The environmental history of several major river systems of the Puget Lowland includes periodic geologic disturbances from lahars (volcanic debris flows) and laharic flooding. Lahars and episodic post-laharic sedimentation have significantly aggraded the Nisqually, Puyallup, White, Skagit, Duwamish, and Nooksack Rivers, caused progradation that has dramatically altered the present coastline, and triggered stream piracy in the Stillaguamish/Skagit River system (Vance, 1957; Beget, 1982), Fraser/Nooksack (Cameron, 1989), and White/Puyallup (Crandell, 1963; Luzier, 1969; Dragovich et al, 1994). These volcanic disturbances buried extensive forests (Pringle and others, 1997; Pringle, 2000; Vallance and Scott, 1997) and destroyed prehistoric human communities (e.g. Hedlund, 1972). Two types of laharic flows have been identified (Scott, 1988, 1989), and observation of flow transformations in noncohesive lahars (Pierson and Scott, 1985) has allowed recognition of lahar runout and laharic flood deposits in downstream areas (Scott and others, 1995; Palmer and others, 1991; Pringle and Palmer, 1992; Dragovich and others, 2000). This history of past volcanism has profound implications for aquifers, seismic hazards (Palmer and others, 1994; Barnhardt and others, 1998), land use, and for future risk.

Influence of Intercepted Landslides on Nearshore Habitat

Timothy J. Walsh, Wendy J. Gerstel, and William H. Graeber
Washington State Department of Natural Resources
Hugh M. Shipman
Washington State Department of Ecology

In the natural landscape, Puget Sound coastal bluffs retreat episodically due to processes of landsliding and erosion. Sediment delivered to the beach by erosion is sorted and redistributed by waves and littoral currents, directly influencing the distribution of beach substrates and habitat types. Coastal armoring alters both the size and frequency of landslides into Puget Sound, affecting the rate and type of sediment deposition within the nearshore environment. Debris disposal often involves direct placement of soil and debris into the intertidal zone, waterward of the seawall or revetment. This approach is expedient and is often the least expensive alternative, but is often undertaken with minimal environmental scrutiny. The frequent use of emergency exemptions and the limited jurisdiction of state agencies on federally-regulated railroad operations often precludes rigorous environmental review, coordinated planning for impacts, and monitoring for effects on habitat. We show several examples of the influence of armoring practices on sediment delivery to Puget Sound and make recommendations for a program to enhance desirable habitat.

Earthquakes in Puget Sound: How Wild a Ride?

Craig S. Weaver
U.S. Geological Survey

Earthquake hazards assessments in Puget Sound are being revised upward. The new USGS estimates incorporate the recently recognized hazard from crustal faults. In 1992 earth scientists discovered shorelines on Bainbridge Island raised as much as 22 feet by an earthquake on the Seattle fault. This was the first time that the possibility of large magnitude (~7) crustal earthquakes in Puget Sound was seriously considered by the USGS. Since 1992 the USGS has focused geophysical and geological studies on the crustal fault systems in Puget Sound. The results indicate that the hazard from crustal fault earthquakes dominate the earthquake hazards for most of Puget Sound.

The reason USGS earthquake hazard assessments are changing in Puget Sound is the availability of new data. Crustal faults are difficult to study in Puget Sound because they are covered by thick glacial sediments and heavy vegetation. The USGS has used a series of geophysical experiments, supplemented by new geologic mapping, LIDAR, and paleoseismic studies, to piece together new models of crustal fault behavior. These geophysical studies include a regional aeromagnetic survey, shallow marine seismic reflection, deep seismic imaging, and local seismic recording for site response studies.

Results from the improved models of Puget Sound faults have raised the seismic hazard assessments, particularly over the Seattle fault, S. Whidbey Island fault, and the Tacoma fault. The bottom line from these estimates: the ground shakes harder and more frequently in Puget Sound than we previously thought. The new hazard estimates may require stronger design standard for buildings in the area.

SESSION 5A: CHANGES OVER TIME IN THE PUGET SOUND/ GEORGIA BASIN, ROOM 407-409

Temporal Changes In Body Length, Weight And Fecundity Of Coho Salmon (*Oncorhynchus kisutch*) From A Research Hatchery In Puget Sound

Thomas P. Quinn, Jeramie Peterson, and Vincent F. Gallucci
University of Washington

Pacific salmon populations in the Puget Sound basin have been affected by changes in freshwater habitat, marine ecosystems, and by decades of culture in hatcheries. These complex factors make it difficult to ascribe declines of salmon to one cause or another. Nevertheless, long-term records of life history traits can help us detect patterns and infer processes. This paper presents data on coho salmon from the University of Washington's hatchery in the Lake Washington basin. Since the late 1950s, adult coho salmon have become shorter, from over 600 mm fork length to under 500 mm (range of annual means: 661 in 1965 to 468 in 1997), though the trend has not been steady. In addition, the weight at a standard length (545 mm, the long-term mean) has decreased from about 1.95 to 1.75 kg, with the decline most evident since about 1980. Overall mean weight has decreased by half, from about 3 to 1.5 kg. As body size declined, the fish have tended to conserve egg size at a cost to fecundity, which is now lower on an absolute basis and lower relative to body size than in the past. Such reductions in fecundity by wild salmon would imply much less productive populations at decreased body size.

Survey-Based Stock Trends for Puget Sound Groundfishes: Monitoring the Road to Recovery

Wayne A. Palsson
Washington State Department of Fish and Wildlife

Many species of groundfishes in Puget Sound have shown dramatic declines in fishing success. These indices have been used a proxies for long-term population trends, and have, in part, led to an Endangered Species Act petition for six groundfishes. Management measures have been instituted to curtail directed fishing at depressed populations, but once these tools are implemented, the proxy measures are affected in unknown manners. Since 1987, the Washington State Department of Fish and Wildlife has undertaken direct population surveys to estimate population abundance of key groundfish species. The survey methods include the use of trawls, scientific echosounders, a quantitative video sampler, and scuba transects. These methods and survey schemes are described and their estimates are compared to fishery-based indices. Although the surveys do not extend to the early periods of high fishing success, many of the trends agree with the measures of fishing success. The direct population surveys also provide tools to continue assessing population trends where fishing has been discontinued and to evaluate the success of conservation measures enacted to rebuild depressed groundfish populations.

Temporal Trends in the Areal Extent of Canopy-forming Kelp Beds Along the Strait of Juan de Fuca and Washington's Outer Coast

Helen Berry
Washington State Department of Natural Resources
Bob Van Wagenon
Ecoscan Resource Data

The Nearshore Habitat Program has inventoried canopy-forming kelp along the Strait of Juan de Fuca and Washington's Outer coast annually since 1989 using aerial photography. Preliminary analysis of the 1989-1998 data set shows that the areal extent of kelp varied highly from year to year, changes in kelp extent were significantly different in 6 out of the 8 yearly comparisons (95 percent confidence interval). The extent of kelp was lowest in 1997 (722 hectares) and greatest in 1998 (1353 hectares). In spite of high yearly variability, no long term trend is apparent between 1989 and 1998, which suggests that the population may be stable. The species composition of the floating kelp beds varied greatly from year to year, reflecting the different responses of bull kelp (*Nereocystis leutkana*) and giant kelp (*Macrocystis integrifolia*) to environmental conditions. Other differences between species of floating kelp were also evident. Bull kelp populations consistently occurred in lower densities and showed much higher year-to-year variation in total extent. Comparison of this long term kelp canopy data to other environmental information could provide insight into how kelp responds to natural and human impacts. Additionally, it could be used to better understand trends in species that utilize kelp habitats.

Long-term Contaminant Trends and Patterns in Puget Sound, the Straits of Juan de Fuca, and the Pacific Coast: Implications for Monitoring and Management

Alan J. Mearns
National Oceanic and Atmospheric Administration

Existing data on contaminants in dated sediment cores from Puget Sound, and in mussels from the entire U.S. Pacific Coast (65 sites), including Puget Sound (15 sites), were re-examined to evaluate geographical patterns, long-term trends, and signs of effectiveness of contaminant management actions. As previously reported, the dated cores reveal a century-long (1890 -1990) rise and fall of chemical contamination in the Puget Sound. Further examination also reveals possible long-term processes that may have transported materials, such as arsenic, across basins. The Mussel Watch Program data begin where the core end (late 1980's). Both cores and mussels from the Sound confirm that PCB concentrations have been declining over the past three to four decades. However, there have been no trends for most metals. Compared to mussels from other Pacific coastal sites those within Puget Sound and the Straits contain lower concentrations of several metals (arsenic and cadmium), similar concentrations of other metals, concentrations of PCBs that are similar to other urban areas, but extremely high concentrations of PAH's. To understand and derive benefit from contaminant management actions, and, ultimately, to determine "how clean is clean enough?", these kinds of long-term region-wide contaminant monitoring programs should be maintained, if not enhanced.

A Dynamic Ecosystem Model of South Puget Sound

Dave Preikshot and Alasdair Beattie
University of British Columbia Fisheries Centre

A dynamic ecosystem model of South Puget Sound (SPS), i.e., South of Tacoma Narrows, was constructed to simulate changes in different species groups during the period from 1970 to the end of the century. This model was built using the Ecopath with Ecosim (EwE) software, developed at the UBC Fisheries Centre, and was parameterised by eliciting information from governmental, university, and private researchers, in combination with data published in the primary literature. This model provides a platform to generate testable hypotheses regarding proximate and ultimate population dynamics in the SPS area. The model also provides a platform upon which different ecosystem management policies, or ecosystem regimes, can be gamed and explored.

SESSION 5B: ECOLOGICAL MODELING AND ASSESSMENT, ROOM 405-406

Hake and Euphausiid Monitoring in the Strait of Georgia Using Hydroacoustics

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R. Kieser
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K. Cooke

Hydroacoustics is an efficient method to measure biological distributions and biomass within a semi-enclosed body of water, such as the Strait of Georgia. Euphausiids or krill are a major food source for several commercially important finfish, including Pacific hake (*Merluccius productus*) within the Strait. Our surveys employed the use of a dual-frequency (38, 120 kHz) echosounding system to measure the distributions of euphausiids and hake within the Strait in the spring and summer of 2000. Survey lines were spaced approximately 5 NM apart, allowing detailed spatial interpolation (contour mapping) of the results. Surveys were complemented with net trawls for both species at several selected locations. These net trawls also served as a truthing and calibration value for our acoustic data. Young hake (<3 years) within the Strait feed primarily on euphausiids and their spatial distributions are often related to the local euphausiid distributions. The horizontal distributions of the euphausiids are based primarily on tidal cycles and currents since the animals travel vertically to the surface to feed at night. Stomach content analysis noted that young hake feed primarily in the morning as the euphausiids migrate from the surface feeding layers to twilight depths (about 125-175 m) to avoid predation from fish during daylight hours.

Risk Assessment Needs for Land Management Decisions at Cherry Point, Whatcom County, Washington

Carol Piening
Washington State Department of Natural Resources

The Washington State Department of Natural Resources (DNR) is responsible for managing some of the tidelands, all of the marine bedlands, and the associated natural resources along the Cherry Point reach of Puget Sound. Cherry Point historically provided spawning habitat for more than half of Puget Sound's herring population. Herring spawning in this reach has dropped by more than

90 percent from the 1970s. The geography of Cherry Point also allows direct deep-water access for industries and shipping. At present, three industrial facilities lease state lands for deep water piers. Over the years several proposals for additional deep water piers have been made, one of which is pending. DNR must strike a responsible balance between protecting habitat and supporting the needs of commerce and navigation. We are using ecological risk assessment as a tool to help DNR make the decisions to meet these management needs.

Regional Risk Assessment Predictions for the Decline and Future Management of the Cherry Point Herring Stock

Wayne G. Landis, April J. Markiewicz, and Jill Thomas
Western Washington University
Bruce Duncan
U.S. Environmental Protection Agency

The Pacific Herring stock that spawns at Cherry Point, west of Bellingham, WA, has undergone a dramatic decline in the past 10 years. We conducted a regional ecological risk assessment using the relative risk model (RRM) to investigate the causes of the current decline, current risks to the population, and the outcomes of future management options. The RRM incorporates geographic location and multiple anthropogenic and natural stressors into estimating risk. In addition to the population decline of the herring, we also see a collapse of the age structure, reduction of recruitment from other populations, and a decrease of the spawning range. The retrospective risk assessment identified overexploitation as the primary risk factor. Warmer sea surface temperatures associated with a warm Pacific Decadal Oscillation have contributed to a lack of recruitment from northern herring populations. Current risk factors to the reduced population center on the destruction of the spawning habitat at Whitehorn Point from spills, development, and natural alterations to the environment. Included in our assessments are testable risk hypotheses and estimates of uncertainty. The relative risk methodology is adaptable to a variety of risk assessment and decision-making processes within the Puget Sound and coastal regions of this state.

Expanding the Use of the Benthic Invertebrate Monitoring Approach Developed for the Fraser River Basin to Assess Streams in the Georgia Basin

Stephanie Sylvestre
Aquatic and Atmospheric Sciences Division, Environment Canada
Trefor Reynoldson,
National Water Research Institute, Environment Canada
Taina Tuominen
Aquatic and Atmospheric Sciences Division, Environment Canada

The establishment of the reference condition approach to benthic invertebrate monitoring in the Fraser River Basin in British Columbia has proved to be a useful tool for assessing streams within the basin. In 1998, as part of the Georgia Basin Ecosystem Initiative, this reference condition approach was extended to include the Georgia Basin (lower Fraser River). Disturbed streams in the Georgia Basin are exposed to heavy recreational, urban and agricultural pressures and tend to be slow moving, deep channel, soft bottom streams. In the development of the initial Fraser River database only fast flowing streams with cobble substrates were sampled. We have expanded that database to assess the health of slow moving streams with soft bottoms. Reference streams with these characteristics were added to the database and a new predictive model for agricultural and urban test sites was developed. This new model allows the assessment of many disturbed streams in the Georgia Basin. The assessment of 12 test sites exposed to agricultural and residential activities varied from “not stressed” for a stream running through a small residential development to “very stressed” for a stream running through agricultural land. In 1999 and 2000, 12 additional sites exposed to urban activities in the Greater Vancouver area were also sampled to test for levels of environmental stress using the modified Fraser River Basin model.

Water Quality Assessment of Urban and Agricultural Run-off Using a Mesocosm Approach in the Lower Fraser River Valley

Mark Sekela, Stephanie Sylvestre, Gail Moyle, and Taina Tuominen
Environment Canada

Cutthroat trout and signal crayfish are being used as biological indicators of water quality impacts from agricultural and urban run off in the lower Fraser River Valley in British Columbia. Intensive agricultural practices exist in the valley, with growing urban populations. Stream-side flow-through aquaria, we refer to as mesocosms, were set up along Elk Creek in Chilliwack at three locations; upstream of human impact,

mid stream of agricultural influences and downstream of agricultural and residential influences. One mesocosm was also set up along Yorkson Creek in Langley to assess water quality impacts of residential, commercial and light industrial areas. Hatchery raised organisms were exposed to fall and spring run off for a period of 2 months, during a time of manure spreading, pesticide application and heavy rains. The organisms were sacrificed at the end of the exposure and analysed for indicators of effects from non-point source pollution and endocrine disrupting substances. Such indicators include vitellogenin induction, MFO induction, intersex in gonads, histological assessments of tissues, and contaminant concentrations in muscle. Water quality (e.g. pH, conductivity, temperature) was also monitored throughout the study. At each location, water samples were taken regularly for metals analyses and a single integrated sample over the 2 month period was analysed for organic contaminants. Preliminary results of MFO induction and metal concentrations indicate increased contaminant exposure downstream of human activities.

SESSION 5C: CIRCULATION, CURRENTS AND WATER PROPERTIES, ROOM 402-403

PRISM Semi-annual Oceanographic Survey of Puget Sound: Overview and Water Mass Results

Mitsuhiro Kawase
University of Washington
Jan Newton
Washington State Department of Ecology
Mark Warner
University of Washington

In June 1998, University of Washington's PRISM project, in collaboration with Washington State Department of Ecology, initiated a comprehensive oceanographic survey of Puget Sound and the eastern Strait of Juan de Fuca. Since then, this survey has been repeated every June and December up to now, with an additional survey conducted in August 1999. The survey uses the University's R/V Thomas G. Thompson, with the State of Washington providing ship-time support. This is the first time in two decades in which a regular oceanographic survey of Puget Sound is conducted with a comprehensive coverage, high spatial resolution and modern analytical techniques. A great emphasis is placed on student participation, and student volunteers work side by side with scientists from the University and state and local governments. Data collected include CTD, oxygen, fluorescence, transmissivity and PAR from electronic sensors; oxygen, nutrients, chlorophyll, dissolved organic compounds and chlorofluorocarbons from bottle samples; and measurement of primary productivity from on-board incubation experiments. Data from these cruises are used for calibration of circulation models of Puget Sound. In this talk we present results of hydrographic measurements and discuss water masses in Puget Sound and their seasonal and interannual variability.

The Distribution and Mechanisms of Mixing in the Main Basin of Puget Sound

John B. Mickett and Dr. Michael C. Gregg
University of Washington
Harvey E. Seim
University of North Carolina

We present observations that describe the distribution and mechanisms of mixing in the main basin of Puget Sound using velocity, density, and turbulent-microstructure profiles. In May and June of 1988, we conducted four 8-10 hour time series at various locations in the main basin. We collected microstructure and density profiles from the Advanced Microstructure Instrument at 8 minute intervals and velocities from an acoustic Doppler profiler averaged over 2 minute intervals. Results of calculated dissipation rates, ε, and diapycnal diffusivities, K_ρ, show background values to be comparable to those in the open ocean; 1×10^{-8} W/kg and 1×10^{-5} m^2s^{-1}, respectively. We observed higher values of ε and K_ρ (3×10^{-6} W/kg and 3×10^{-3} m^2s^{-1}) in regions of increased vertical shear ($\sim 1 \times 10^{-2}$ s^{-1}) caused by mid-depth intrusions and bottom boundary layers. The warm and fresh mid-depth intrusions are also susceptible to double diffusive processes, another potential mechanism for mixing. An understanding of mixing in the main basin of Puget Sound is critical because of its close link to water mass renewal and importance to the development of accurate and realistic circulation models.

Flow in the Strait of Juan de Fuca

Kathleen Edwards, Parker MacCready, Geno Pawlak, and Ryan McCabe
University of Washington

Coastal mixing is of practical interest in the Strait of Juan de Fuca due to the industrial sites on its shores and its heavy shipping traffic. One source of mixing in the Strait

is coastal topography. As water is driven through the Strait by the tides, it is stirred by irregularities on the coastal wall, such as 1-km wide underwater bumps. We present observations of this mixing process which were collected on a June 2000 research cruise. During surveys along the Strait's northern slope, the ship's ADCP recorded velocity profiles throughout the tidal cycle. Supplementing these data were CTD casts, moored ADCP measurements, and thermistor chains at the eastern mouth of the Strait. This paper presents the picture of coastal mixing which is captured by these data. The goals of the study are 1) to supplement limited observations within the Strait and 2) to understand the effect of wall roughness on tidal flows.

Tidal Eddy Generation at Three Tree Point in Puget Sound, Washington: Theory and Numerical Modeling

Parker MacCready and Geno Pawlak
University of Washington

The rate of vertical mixing and horizontal stirring within Puget Sound is governed by the interaction of stratified tidal currents with the complex fjord bathymetry. We present theoretical predictions regarding stratified flow along a slope with a ridge. Depending upon the stratification, slope angle, flow speed, and ridge geometry, the ridge may or may not generate strong internal waves. Faster flow tends to generate waves, while slower flow does not, but does give rise to horizontal flow separation and tidal eddy generation. In both cases we find the pressure drag on the ridge may be substantial, and is well-parameterized by a drag coefficient of order one, based on frontal area. The theory compares well with idealized 3-D numerical simulations. The numerical model is then applied to flow near Three Tree Point, in the main basin of Puget Sound. The model predicts strong eddy generation. Interestingly the model also predicts that the drag is asymmetric, giving rise to a net landward force, which may in part explain the Vashon Island Recirculation. This recirculation is usually assumed to be forced by dynamics near Pt. Defiance.

High Resolution Temperature and Salinity Profiles in Possession Sound with an Autonumous Underwater Vehicle

Andrew M. Chiodi, Charles C. Eriksen, Russel D. Light, Timothy Wen, and Thomas W. Lehman
University of Washington

The Seaglider, a novel autonomous underwater vehicle developed at the University of Washington, was deployed in Possession Sound for 28 days from 22 June 2000 until 19 July 2000, in order to better understand the vehicle's performance characteristics and to obtain high resolution vertical profiles of temperature and salinity. The Seaglider is a small, buoyancy driven, instrument, equipped with GPS and cell phone systems. The Seaglider was made to glide from the surface to depths of approximately 150 meters and back to the surface, while directly measuring temperature, conductivity and pressure, with approximately a 0.5 meter vertical resolution. Over 440 dive cycles were performed during the 28 day deployment, resulting in 880 separate vertical profiles of temperature and salinity. The depth averaged current is measured during a dive cycle. Surface currents are measured in times between dives. The depth averaged current resembles model predictions of the tidal current in Possession Sound. The surface current is biased strongly towards the southwest, consistent with the expected estuarine circulation. Fresh water content in the upper 20 meters is correlated with the flow rates of the Skagit and Snohomish rivers. Water mass properties below 20 meters appear to vary independently from the surface conditions.

SESSION 5D: LONG-TERM SCIENCE PLAN FOR THE OLYMPIC COAST MARINE SANCTUARY, ROOM 404

SESSION 6A: FISH ECOLOGY AND BIOLOGY, ROOM 407-409

Short Wavelength Vision in Larval Fishes: A Feeding Adaptation?

Lyle L. Britt, William McFarland, and Bruce S. Miller
University of Washington

Virtually all larval fishes are known to be obligate particulate planktivores and are almost solely dependent upon their visual capabilities in order to locate and capture prey. Thus, their survival is, in essence, a matter of "seeing" their prey and our knowledge of the visual capabilities of larval fishes is very limited. A single previous study demonstrated that larval fishes that possess a UV visual pigment were also capable of feeding upon zooplankton when exposed to only ultraviolet light. In this study, using microspectrophotometric techniques, we found that 85 percent (17 out of 21) of the larval fishes tested from the Pacific Northwest possessed a short wavelength photoreceptor. Behavioral feeding

experiments on three of these species revealed that they could feed effectively solely in the presence of ultraviolet light. Additionally, examination of the larval diet of two of these species revealed a strong correlation between ontogenetic changes in vision physiology and ontogenetic diet shifts. If larval fish are dependent upon short wavelength light in order to successfully feed, then what are the effects of pollution which tends reduce the level of penetration of short wavelength light, and conversely, what is the effect on larval fish vision of increased short wavelength radiation (especially UV-B) that occurs from ozone reduction, particularly at high latitudes?

A Marine Preserve in San Juan Channel: Is it Working for Nearshore Rocky Reef Fish?

Eric Eisenhardt
University of Washington

Objective: Compare abundance and length-frequency distributions of Scorpaenid (rockfish) and Hexagrammid (lingcod and greenlings) fishes inside reserves versus outside reserves.

General Methodology: Non-reserve sites were paired with reserve sites to provide similar substrate, habitat, and oceanographic positioning in the Channel. Visual belt transect surveys via SCUBA were used to collect data; including, for individual fish: species, length (to cm), and depth, and for each transect: physical and biological habitat data. In addition, fishing activity surveys were completed.

Results: Preliminary data supports the hypothesis that species subjected to a directed fishery are more abundant and larger inside marine reserves compared to outside. Abundance of young-of-the-year (**YOY**) *Sebastes caurinus* (copper rockfish) did not show any consistent pattern between reserve and non-reserve sites. Work is in progress and analysis will be completed by February.

Significant Conclusions: Reserves contain more abundant and larger fish, and therefore increased reproductive output. Reserves should be sited in close proximity to dispersal providing oceanographic features. Protecting nursery habitat from degradation is probably more important to YOY recruitment. More detailed conclusions will be made by February.

Practical Applications: To provide empirical, statistically rigorous data regarding rocky reef marine reserves and aid in the siting and design of reserve networks.

Micro- and Macro-habitat Relationships for Rockfish, Lingcod, and Other Rocky Reefs Fishes in Puget Sound

Robert E. Pacunski and Wayne A. Palsson
Washington State Department of Fish and Wildlife

Rockfish, lingcod, and other fishes inhabit a range of rocky or hard-bottom habitats throughout Puget Sound. Many of these populations are in depressed condition and appear to be vulnerable to fishing and other nearshore threats. Earlier work by the Washington State Department of Fish and Wildlife has identified the general affinities of rockfish to their habitats. However, more specific information on the specific habitat requirements of reef fishes is required to plan marine protected areas and implement habitat and conservation measures.

Scuba, video, and acoustic surveys have been conducted in Puget Sound, Washington State since 1992. These surveys have provided observations of fish densities in association with major and minor habitat features. Using stepwise regression and other multivariate techniques, a model for reef fish habitat associations has been developed for copper rockfish (*Sebastes caurinus*), quillback rockfish (*Sebastes maliger*), brown rockfish (*Sebastes auriculatus*), lingcod (*Ophipdon elongatus*), and kelp greenling (*Hexagrammus decagrammos*). Key variables for most reef species were substrate type, vertical relief, and complexity (number of crevices). Copper rockfish showed a high association with boulder fields and less usage of walls and small rock rubble while quillback rockfish were more associated with high relief habitats. Most of the sedentary rockfish species were associated with habitats containing high relief and complexity but lingcod were less responsive to these variables. Observed habitat associations may be in part the result of fishing and comparisons to patterns between fished areas and marine protected areas may help to identify the effects of fishing on habitat use by reef fishes.

Abundance, Mate and Site Fidelity of Wolf-eel in Puget Sound, Washington

Tony R. Parra, Wayne A. Palsson, and Robert Pacunski
Washington State Department of Fish and Wildlife

Wolf-eel (*Anarrhichthys ocellatus*) are predators of economically and ecologically important invertebrates, yet little is known of their life history. We undertook a scuba observation study to examine seasonal and annual patterns of abundance, site and mate fidelity, and the behavioral interactions of wolf-eel in rocky reef communities. Transects were established at two sites in Puget Sound and monthly surveys have been conducted since December 1998. Individuals are identified using visible elastomer tags and by recognition of naturally occurring marks.

Observations indicate that wolf-eel exhibit significant mate and site fidelity during the winter spawning season only. We recorded 44 movements of individuals between dens, seven of which included the positive identification of individuals that selected new mates. Three wolf-eel occupying the same den were recorded on several occasions. Abundance of wolf-eel has not varied between seasons or years surveyed.

Wolf-eel compete with Pacific giant octopus (*Octopus dolfeini*), as evidenced by octopus displacing wolf-eel, particularly during spring months. Other species observed in association with wolf-eel include sailfin sculpin (*Nautichthys oculofasciatus*), rockfish (*Sebastes* spp.), and lingcod (*Ophiodon elongatus*). Three instances of lingcod nesting in occupied wolf-eel dens were observed, and it is unclear whether the relationship between these species is commensal or competitive.

SESSION 6B: RESTORATION PROJECTS, ROOM 405-406

Washington State Wetland Mitigation Evaluation Study

Patricia A. Johnson and Dana L. Mock
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Emily J. Teachout
U.S. Fish and Wildlife Service
Andy McMillan
Washington State Department of Ecology

This study was undertaken to assess the effectiveness of compensatory wetland mitigation statewide. The study investigates both the level of permit compliance and ecological functioning of a random sample of wetland mitigation projects in Washington. Forty-five projects were evaluated in Phase 1 to determine the degree of compliance with permit requirements. Compliance was evaluated in three parts: 1) Was the mitigation project implemented? 2) Was it implemented to plan? and 3) Was it meeting its performance standards (as assessed by this study)? Less than a third of the projects were in full compliance with all three questions. However, most projects were implemented. Recommendations to improve compliance were aimed at permitting agencies.

Phase 2 will determine how the mitigation sites function ecologically (including establishment of wetland area); how the mitigation site compares to what was impacted; and what factors correlate with the success or failure of the project. Twenty-four projects are being assessed, and preliminary results indicate that over 90 percent of the required wetland acreage was established. However, more than half of the required acreage was to be enhancement of pre-existing degraded wetlands. A final report of Phase 2 results is expected in the spring of 2001.

A Monitoring Plan for Intertidal Habitat Restoration in the Duwamish River Estuary

Curtis D. Tanner and David Low
U.S. Fish and Wildlife Service

A series of four intertidal habitat restoration projects are being completed in the Duwamish River estuary (Seattle, WA) by the Elliott Bay/Duwamish Restoration Program (EB/DRP). The U.S. Fish and Wildlife Service (FWS) has prepared a monitoring plan for EB/DRP to evaluate project success. FWS will implement this plan on behalf of EB/DRP, beginning in post project year one (2001) and continuing for a ten year period through 2011. The monitoring plan provides detailed success criteria for both physical (5) and biological (7) attributes to be used to determine if project objectives have been met. Monitoring tasks and contingency measures are described for each of these criteria. Estimated monitoring program costs are approximately 15 percent of the total restoration program construction budget (exclusive of land acquisition costs). This plan provides a useful example of a close relationship between ecological objectives, success criteria, monitoring tasks, and contingency measures that are important features of an effective approach to monitoring.

Sqaully Beach: Challenges of Urban Restoration

Colin Wagoner, P.E.
Ridolfi Engineers, Inc.
Jennifer Steger
National Oceanic and Atmospheric Administration

The Commencement Bay Trustees selected Squally Beach as a habitat restoration site because it was in a relatively unimpacted area of the heavily industrialized of the Tacoma Tideflats. A corner of the site supporting a lush bed of *Carex lyngbyei* hinted at the potential for a small but thriving upper salt marsh environment. Stormwater flowing under the site through culverts offered the

possibility of mixing fresh water with salt water to increase the variety of plants that could be grown.

Ridolfi Engineers led a team that developed two conceptual designs intended to maximize the area at appropriate elevations and use the fresh water throughout the site. Other considerations were, potential for use of the site as a nursery, beach stability and passive public access. Public input was solicited in Trustee meetings and incorporated into the final design. Permitting was a challenge because regulators have a difficult time fitting restoration projects into existing boxes. Construction has provided additional challenges but was successfully implemented in the end. Public involvement will drive the next phase of the project as both upland and salt marsh plants will be installed by volunteers. Biological, physical and chemical monitoring protocols are also being developed.

SESSION 6C: SPILLS, ROOM 402-403

Injury, Restoration and Recovery of Fish and Wildlife Resources Following the Olympic Pipeline Gasoline Spill in Whatcom Creek, Bellingham, Washington

Daniel Doty and Charmane Ashbrook
Washington State Department of Fish and Wildlife

On June 10, 1999, a pipeline owned and operated by Olympic Pipeline Company (OPL) ruptured and spilled approximately 277,000 gallons of gasoline into Hannah and Whatcom Creeks in Bellingham, Washington. The gasoline flowed downstream and exploded, burning over 25 acres of riparian habitat and impacting over three miles of stream. Immediately following the spill, natural resource trustees and OPL began cooperative surveys to assess natural resource injuries and to identify emergency remediation and restoration actions in the stream. The objectives of this presentation are to discuss results of fish and wildlife injury assessments, to describe some of the emergency restoration efforts, and to discuss results of ongoing monitoring studies.

Results of stream surveys indicate that the aquatic ecosystem was severely impacted by the incident. Over 100,000 dead fish (including salmon and trout), aquatic invertebrates, amphibians, birds and mammals were found in 3 miles of creek downstream of the spill.

Since the spill, a variety of in-stream remediation and habitat improvements have been implemented. Ongoing monitoring studies suggest that the stream community is beginning to recover and that remediation and restoration efforts have helped. Full recovery is expected to take years and long-term restoration projects are now being planned.

The cooperative working relationship between resource trustees and OPL has helped facilitate rapid implementation of restoration projects in the creek. The lessons learned in this incident can serve as a model for future spills.

Dispersing Oil Spills in the Straits: Assessing Fisheries and Environmental Tradeoffs

Alan Mearns, Jeff Lankford and Glen Watabayashi
National Oceanic and Atmospheric Administration

To be effective, oil spill response options - such as use of dispersants and in situ burning - must be pre-approved, with the understanding that there are tradeoffs with every action. To help resource managers evaluate response options we developed alternative "what-if" oil spill scenarios for the Straits of Juan de Fuca and other near-coastal areas. For dispersed oil scenarios we parameterized 3-D circulation models providing time series of Expected Environmental Concentrations (EC's) of dispersed oils and fuels. During several Ecological Risk Assessment Workshops, these "pulse" or fast-changing plume concentrations were compared to "concentrations of concern" developed by consensus of fishery biologists using existing and new data on oil and dispersant toxicity and effects. The risks to fishery and water column resources from dispersed and alternative response scenarios were then compared to risks of the same scenarios to sea birds, cetaceans, sea otters, seals and sensitive nearshore and shoreline habitats such as kelp beds, marshes and protected areas. Risk assessments done to date indicate that even in nearshore and shallow waters of the Straits of Juan de Fuca, rapidly dispersing oil may not be the hazard once thought, while reducing risk to seabirds, sea otters, seals and shorelines. While more resource scientists are now prepared to support dispersant pre-approval, the final decisions will still require input from the political, social and economic sectors. Regardless of the outcome, we propose that cooperative, inter-agency, semi-quantitative ecological risk assessment efforts, supported by realistic scenarios and simple (parameterized) models, can play important roles in evaluating the effectiveness and tradeoffs of a wide range of marine resource protection and management options.

Surface Microlayer Monitoring in Georgia Strait

Brent Moore
British Columbia Ministry of Environment, Lands and Parks

For many years sediments have been recognized as a sink for a large number of contaminants that enter the marine environment. Over the last three decades, it has also been determined that the surface microlayer of marine waters can be an area of contaminant concentration, especially for chemicals such as pesticides, metals and chlorinated hydrocarbons. The surface microlayer, approximately 50 microns thick, is the atmospheric interface with the aquatic environment; thus, contaminants from both atmospheric deposition and terrestrial runoff can concentrate in this layer. Toxins in the microlayer can be 100 to 10,000 times higher than in the water column below, and can potentially cause significant impacts to the eggs and/or larvae of marine organisms that utilize the microlayer as 'nurseries'. It has also been shown that tidal action can coat intertidal organisms with the microlayer contaminant concentrations. Monitoring has been conducted previously in areas such as Chesapeake Bay and Puget Sound, with elevated contaminant levels and direct toxicity measurements being recorded. The Ministry has initiated a preliminary sampling program in Burrard Inlet and other Georgia Strait waters to determine whether or not microlayer contamination can potentially impact on marine life here. A locally developed rotating drum sampler has been utilized in the last year to collect a limited number of samples. Contaminant elevations in the microlayer have been measured.

Spill Prevention... Knowing What To Do Isn't Enough!

Eric Olsson
University of Washington Sea Grant Program

You are now a marina manager. Boaters look to you for safe moorage and a place to store and maintain their boats while the general public increasingly assumes that your facilities will provide access to their waters. Your professional life has become more complex in recent years as greater emphasis has been placed on water quality issues and the sustainability and survival of many marine resources. As a marina manager you are confronted with many, and often conflicting, user needs. Your marina and repair facilities are under greater public and agency scrutiny. How do you respond to these pressures to meet boater demands for service while preserving the quality of your marina environment?

Knowing effective oil spill prevention and response measures may let you sleep soundly, but it may be time to wake up to how local, state and federal enforcement agencies view the adequacy of your plans. All marinas need a written spill prevention and response plan that must include sound best management practices, BMPs, and valid spill notification and response procedures that include staff training and drills. The development of these plans must start with a complete audit of your facility and adjacent operations and also address the risks posed by moored and transient vessels and their maintenance activities. After you assess the extent of your exposure to these spill risks, it is time to meet with your staff to develop the initial draft of your plan–the blueprint for meeting both regulatory and environmental stewardship obligations and minimizing your exposure to liability and risk.

SESSION 6D: SIXGILL SHARK, ROOM 404

Natural History of the Sixgill Shark, *Hexanchus griseus* (Bonnaterre1788)

John H. Rupp
Point Defiance Public Aquarium

Sixgill sharks are putatively deep water organisms found in most temperate and sub tropical seas and are one of the largest non-plankton feeding sharks. The development of SCUBA (Self Contained Breathing apparatus) in the later half of the 20th century has enabled close observation of these sharks in shallow water suggesting a life history component perhaps critical to reproduction and or maturation. This paper summarizes current knowledge of sixgill distribution and abundance, feeding habits, reproductive biology, age and growth. Emphasis is placed on the unique aspects of "shallow water" sixgills in Puget Sound and Canada.

An Overview of the Commercial Catch of Sixgill Sharks in Washington Waters

Greg Bargmann
Washington State Department of Fish and Wildlife

Sixgill sharks have been exploited in Puget Sound for over fifty years. In the 1940's and 1950's, the fish were captured by commercial fisheries primarily for use of their livers. Sixgill sharks were commonly sold under other names such as "mud sharks". Often, only the liver would be landed and identified only as "shark liver". Therefore, it is not possible to accurately estimate the

magnitude of commercial landings. In the 1950' s the fishery died, due primarily to declining market demand for shark livers.

From the 1950's to 2000 there was very little harvest of sixgills in Puget Sound, except for occasional bycatch in a commercial or recreational fishery. In 2000, a targeted recreational fishery for sixgills began in Elliott Bay near Seattle. This fishery caught four sharks in approximately one week in just one area. The fishery generated considerable public attention and appeared to have the potential for rapid growth. The Department of Fish and Wildlife closed Puget Sound to the recreational harvest of sixgills by emergency order and is now considering making the prohibition permanent.

A Review of British Columbia Landings/Regulations and Assessments

Rick Harbo
Fisheries and Oceans Canada

A Summary of Current Sixgill Shark Research Efforts by Canadian And US Investigators

Vincent F. Gallucci
University of Washington

SESSION 7A: ECOSYSTEM SCIENCE AND STEWARDSHIP, ROOM 407-409

Preaching to a New Choir: COASST and Citizen Science

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University of Washington,
School of Aquatic and Fishery Sciences

COASST (Coastal Observation and Seabird Survey Team) is a Washington-based beached bird survey program designed to couple “hard science” with “public outreach.” By monitoring the deposition of beachcast carcasses, COASST volunteers provide high quality data on the status and trends of coastal resources—mainly seabirds—for the tripartite purposes of science, informed management and conservation, and proactive citizen involvement and action. Most COASST volunteers are drawn from coastal communities and lack field experience with bird—so how can local beachcombers become effective citizen scientists and stewards? By emphasizing simplicity and redundancy in its field guide and data sheets, COASST invites participation by lay persons while ensuring high data quality (in their initial year COASSTers have enjoyed > 90 percent success in bird identification). Frequent and timely interactions among volunteers and COASST coordinators (both in person and via our interactive web site) stimulate even more activity and improve accuracy. In this presentation, we will outline these methods and our first-year results. We will also discuss the rapid expansion of the program in terms of volunteer numbers, partnerships, and geographic coverage. Finally, we will discuss how COASST uses beached birds as indicators of the health of the nearshore environment through stable isotope analyses, mark-recapture studies, and so on.

Targeting Habitat Conservation and Protection Efforts in Puget Sound: Whatcom County Marine Resource Committee’s Approach

Paul Schlenger
Anchor Environmental, L.L.C.
Mike Stoner
Port of Bellingham
Tom Schadt
Anchor Environmental, L.L.C.

Through ESA listings of salmon stocks and the continued decline of Puget Sound marine fish populations, regional awareness is growing of the key role of estuaries and nearshore habitats in marine ecosystem health is growing. A recent commission convened by Senator Patty Murray and Representative Jack Metcalf developed a locally based process to create a “science-based regional system of Marine Protected Areas and the protection and restoration of nearshore habitats” in Puget Sound. This process, commonly known as the Northwest Straits Initiative, is currently federally funded for five years. Through the initiative each of seven north Puget Sound counties have established Marine Resource Committees (MRCs) to coordinate marine conservation.

In Whatcom County, the MRC has implemented a two-phase approach to meet the following objectives: 1) identify and prioritize potential habitat protection and restoration opportunities in coastal waters, and 2) develop a long-term strategy for marine habitat restoration. The first phase was to prepare a GIS based compilation of historical and current data on the marine resources and coastal processes of the county. In the second phase, to be completed by February 2001, specific objectives for habitat restoration and protection will be developed and the areas of opportunity identified and prioritized.

The Rapid Shoreline Inventory: A New Partnership Program for Collection of Detailed Habitat Data from Puget Sound Shorelines by Volunteers

Lisa Younger, Zach Ferdana, Tom Dean, and Jacques White
People for Puget Sound
Kevin Ranker
Friends of the San Juans

Both a lack of compiled information and gaps in critical information are preventing marine scientists and nearshore policy experts from developing a thorough understanding of nearshore conditions and resource management needs in the Puget Sound basin. The Rapid Shoreline Inventory (RSI) is a new project created by People for Puget Sound that links the information needs of local resource managers to well-trained volunteer stewards who collect detailed data about marine and estuarine shorelines. The RSI consists of 4 key components: 1) identification of resource information needs, 2) careful classroom and field training of volunteers, 3) a rapid inventory of contiguous 150 ft. sections of Puget Sound shoreline, and 4) creation and maintenance of the associated GIS database and web site. The project was piloted in the summer of 2000 on Kitsap, San Juan and Whatcom County shorelines. Results of the initial year of investigation will be presented.

SESSION 7B: EMERGING ISSUES, ROOM 405-406

Sorting Out Cumulative Effects of Multiple Stressors on Eelgrass Transplants in Puget Sound

Ronald M. Thom, John Southard, Amy Borde, Gregory Williams, and Susan Blanton
Battelle Marine Sciences Laboratory

We have been monitoring several restored eelgrass meadows in Puget Sound and in the Northwest, and have found variable success in terms of the systems achieving identified goals. The monitoring has shown (1) early transplant survival is moderate, and no greater than 80 percent under optimal circumstances; (2) spread of eelgrass transplants is slow, and under optimal (mesocosm) conditions may take 2 years to occur; (3) spread may depend on below-ground organic matter and processes, as well as on grazers and predators; (4) as the meadow matures, plant size may increase as density decreases, indicating that measures in addition to shoot density should be used; (5) higher than normal summer temperatures, seaweed blooms, bioturbator activity, propeller scars, anchor chain drag, and boat wakes may act as cumulative multiple stressors of eelgrass transplants; (6) sites with marginal conditions for eelgrass may support eelgrass in “good” years but may be unsuitable during other years; (7) site assessments and experimental plantings are useful in evaluating a site prior to full transplanting; (8) monitoring should be conducted for at least 5 years following planting to understand long-term sustainability of the system; and, (9) reference sites are critical to interpreting results.

Cultural Perspectives of Environmental Assessment in Grays Harbor, Washington

Teresa Ryan, MS
University of British Columbia, Fisheries Centre

The cultural use of saltmarsh plants in estuaries provides a significant biological monitoring tool for environmental assessments. Recognition of natural resources as cultural resources provides a unique approach for resource management by integrating the foundations of science, law, and traditional ecological knowledge (TEK). Sweetgrass (*Schoenoplectus pungens*), is used by North American Natives as a material culture natural resource in the manufacture of baskets. The plant is a component, and participant, in highly complex estuarine ecosystem processes. Disruptions to ecosystem processes may be evidenced in (*Sch. pungens*) populations in Grays Harbor, Washington. Using TEK with science and law may improve resource management processes by recognizing the value and use of natural resources with a cultural value. This approach includes the human element as a part of the environment, similar to North American Native cultural value of the natural world. It is a holistic approach for estuarine management processes.

Sublethal Effects of Contaminants on Fish in Puget Sound: What Is Their Significance?

T.K. Collier, M.R.Arkoosh, L.L. Johnson, J.P. Meador, M.S. Myers, and N.L. Scholz
National Oceanic and Atmospheric Administration

What's Next For Puget Sound Science—Issues Identified Through the Ambient Monitoring of Puget Sound

Scott B. Redman
Puget Sound Water Quality Action Team

The Puget Sound Ambient Monitoring Program (PSAMP) is an interagency effort to assess the condition of Puget Sound and its resources. As they present PSAMP findings, the program's scientific investigators draw conclusions about (1) environmental problems confronting the region, (2) appropriate follow up resource management actions, and (3) what's needed from additional investigation. Each of these conclusions helps to define next steps and future needs for Puget Sound scientific inquiry.

Recent PSAMP results provide examples of the research and management issues emerging from ongoing studies of Puget Sound. For example, research questions raised through PSAMP include:

- Can we describe and measure habitat alteration and degradation related to the modification of Puget Sound shorelines?
- What type and extent of land management practices are needed to keep fecal coliform loading to levels that will not threaten shellfish harvest in the area?
- How do human-caused nutrient loadings to Puget Sound affect water quality and the Sound's biological resources?
- What is the cause of increased incidence of liver lesions in English sole from Elliott Bay over the late 1990s?

These and other questions raised through PSAMP delineate a set of issues that need to be more fully analyzed to evaluate and improve efforts to protect and restore Puget Sound.

Connecting Our "Gut Feelings" to Science by Asking the Right Questions

Tom Mumford
Washington State Department of Natural Resources

SESSION 7C: MARINE OUTFALL SITING STUDY, ROOM 402-403

Circulation Variations in the Northern Main Basin of Puget Sound

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Evans-Hamilton, Inc.
Bruce J. Nairn
King County Department of Natural Resources

Puget Sound connects to the Strait of Juan de Fuca through Admiralty Inlet. The Whidbey Basin connects to the Main Basin at the junction with Admiralty Inlet. There have been relatively few studies in this region, also called the Triple Junction. Important flow characteristics include tidal and wind forcing, estuarine circulation, and coastal ocean variations at the entrance to the Strait. Inflow at depth keeps the Sound from stagnating; outflowing surface water flushes the Sound. Mixing by tides and winds and over Admiralty Inlet sill plays a major role in this process. Most previous studies focused on the along-channel effects. The few cross-channel studies have shown significant variations that affect how waters mix and suggest that the core of maximum outflowing water meanders through the northern Main Basin. Further complexity appears in the Triple Junction due to the large shoal off Whidbey Island.
This paper describes the current state of knowledge of the oceanography that affects the Triple Junction and indicates gaps in understanding. It is important to understand the along- and across-channel flow variations in this region because prevailing currents would affect the fate of discharge from a potential new sewer outfall.

Comparison of Observational Circulation Patterns and Numerical Model Predictions in Puget Sound, Washington

Bruce J. Nairn
King County Department of Natural Resources
Mitsuhiro Kawase
University of Washington

The triple junction at the confluence of Admiralty Inlet, Possession Sound and the Main Basin region of Puget Sound contains a complex circulation pattern formed by tidal and estuarine circulation. The advective and mixing processes within this region are of particular interest to the siting a new municipal wastewater discharge north of Seattle. A 3-D hydrostatic, sigma-coordinate model has been configured for the Puget Sound region based on the Princeton Ocean Model (POM). The model is configured on a 600x900m Cartesian grid and forced with river inflows, surface winds and tidal amplitudes. Comparison is made between model predictions and observational data from eight lagrangian drifters and fixed current moorings. The drifters are configured to telemeter a GPS position via both RF and ARGOS satellite service at a 30 minute interval. The fixed current meter moorings were located in east-west cross-sections and at each inlet to the triple

junction region. We discuss the usefulness of these data-model comparisons in understanding the mean circulation and mixing processes within this system.

Determination of Surface Circulation Patterns in the Northern Puget Sound Using Drift Cards

Kari A. Sauers and Curtis C. Ebbesmeyer
Evans-Hamilton, Inc.
Scott Mickelson
King County Department of Natural Resources

Until recently, few studies have been done to determine the circulation patterns of the northern Puget Sound. A variety of current meters are commonly used for this purpose, however practical constraints limit these instruments from measuring shallower than a few meters depth. The upper few centimeters of the sea surface disperse floatable materials, therefore drift cards offer one of the few practical solutions. Drift cards reflect the effects of advection and dispersion in the surface layer, and therefore are an effective tool for the determination of surface flow under the influence of wind and tidal forcing. Drift cards were released from eight locations in the northern Puget Sound under various combinations of north and south winds and flood and ebb tides. Despite the close proximity of the release sites, results vary substantially by site. Many cards traveled into the Strait of Juan de Fuca, and were found in many well know collection sites including Victoria BC, Dungeness Spit and the San Juan Islands.

Seasonal Patterns and Controlling Factors of Primary Production in Puget Sound Central Basin and Possession Sound

Kara Nakata and Jan Newton
Washington State Department of Ecology
Randy Shuman
King County Department of Natural Resources

Primary production was measured using the carbon-14 uptake method in order to assess production and nutrient dynamics in the Central Basin and Possession Sound regions of Puget Sound. Ambient and nutrient-spiked production rates for the entire euphotic zone were determined every 3-5 weeks at 4 stations from October 1998 to October 2000. Nutrient (nitrogen and phosphate) concentrations, chlorophyll a, incident radiation, temperature, and salinity were also measured to examine factors affecting production rates. Seasonal variation in production is well-defined for all 4 stations, with summertime (May-August) levels as high as 6000 mg C m^{-2} d^{-1} which drop to wintertime lows, usually less than 100 mg C m^{-2} d^{-1}. Like many temperate systems, a summertime low in production was also seen in June-July at all stations. Similar variation in biomass, as measured by chlorophyll a, was also seen. Highest production was recorded from April through September, with the maximal rate not consistently found at any one particular station. Increased production due to the addition of nutrient spike was seen at times at all stations during spring and, more often, summer months. As predicted, nutrient stimulation was not seen at any station in the winter, when light is the primary determinant of production levels. Carbon-14 uptake experiments are continuing at these stations through June 2000 to better determine factors influencing productivity.

Nearshore Habitat Mapping in Puget Sound Using Side Scan Sonar and Underwater Videography

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Jim Norris
Marine Resources Consultants
Sandy Wyllie-Echeverria
University of Washington
Debra MacLellan and Randy Shuman
King County Department of Natural Resources

We used a combination of side-scan sonar and underwater video to map and analyze submerged shallow water habitats in support of a King County Wastewater Treatment Division's Habitat Conservation Plan (HCP) and Marine Outfall Siting Study (MOSS). Using these techniques, we delineated the areal extent and location of eelgrass beds, sediment type and kelp distribution, and mapped the location of benthic macroinvertebrates and fish.

Our study site included approximately 22 km of nearshore habitat between a depth of +1 m and –30 m (mean lower low water) between Shilshole Bay Marina and Picnic Point. We towed side-scan sonar along track lines parallel to shore to develop near real-time, georeferenced mosaics delineating edges and areas of sparse, patchy, or dense eelgrass, and substrate type. To verify the eelgrass signature observed in the side-scan imagery, and map the presence and location of kelp beds, benthic macroinvertebrates and fish, we towed an underwater video camera along complementary track lines. We analyzed the side-scan sonar and video data in a GIS database to establish, and then display, linkages between habitat types and animal assemblages. We found the combination of side scan sonar and underwater video to be a useful tool for conducting relatively rapid and extremely high resolution mapping of nearshore community relationships in Puget Sound.

SESSION 7D: STORMWATER PROBLEMS AND SOLUTIONS, ROOM 404

A Proposed Strategy for Maintaining Ecological Integrity in Urban Streams

Christopher May
University of Washington

Numerous small, lowland streams in the Puget Sound region and their watersheds were studied to identify the linkages between watershed conditions, specifically urbanization, and the habitat elements and biological responses. Measures of ecological integrity declined beginning at the lowest levels of urbanization and continued with no threshold effect. The study produced a set of watershed conditions necessary for proper functioning condition (PFC) in urban salmon streams. Each of these conditions, by themselves are necessary, but not in themselves sufficient. A follow-up study is in progress to assess the influence of structural and non-structural best management practices (BMP's) on the same ecological communities. Preliminary results indicate that retention of a wide, nearly continuous riparian buffer in native vegetation has greater and more flexible potential than other options to uphold biological integrity when development increases. Upland forest retention also offers valuable benefits, especially in managing any development occurring in previously undeveloped or lightly developed watersheds. Structural BMP's appear to have less mitigation potential than the non-structural BMP's assessed and should not be regarded, as they so often are, as the leading or sole mitigation strategy. Still, they have their place in management, especially in moderately and highly developed watersheds, to help prevent further resource deterioration, and, in dense networks along with non-structural means, in less developed basins of relatively high ecological value and sensitivity. None of the options is without limitations, and natural landscape preservation must be incorporated into the development process if we are to protect the remaining aquatic resources.

Detecting Hydrologic Change in High Resource Streams

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From the mid-1980s to the mid-1990s, the King County Basin Planning program conducted detailed aquatic habitat, hydrology, land use, soils, geomorphology, and water quality studies of many stream basins in the urbanizing, western third of the county. Two legacies of this program are calibrated hydrologic models of the basins and an on-going basin monitoring program. These two assets have been used to apply and demonstrate a "synthetic paired watershed" technique. In this approach, recent gaged flows represent a "treated" condition of 10-plus years of land development while contemporaneous simulated flows from models reflecting mid-1980s land use represent the "control". Application of the technique to the upper Bear and Evans Creek basins indicates steep declines in summer base flows as well as increases in winter peak flows in both basins. The synthetic paired basin approach can be a useful tool to detect hydrologic change caused by human activity given accurate precipitation and stream flow data coupled with a well-calibrated model of known accuracy and bias with respect to the flow parameters of interest.

Influence of Land Cover Urbanization on the Biological Condition of Puget Sound Lowland Streams

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Rapid urbanization threatens the condition of streams and rivers across the Pacific Northwest, as demonstrated by the recent ESA listings of Puget Sound salmon. Efforts to protect and restore urban streams have traditionally focused on physical channel conditions and chemical water quality. The objective of this study is to use the biology of these streams—measured with the multimetric index of biological integrity (B-IBI) based on benthic macroinvertebrates—to assess stream condition. Between 1997 and 1999, invertebrate samples were collected from 45 sites in second and third order streams in the Puget Sound lowlands of Western Washington. Urbanization was characterized by a 1998 satellite land cover classification and was measured across several spatial scales. B-IBI declined as urban land cover increased both across the entire upstream basin and within riparian zones. The presence of forested riparian corridors was associated with higher B-IBI. As both a conservation and restoration strategy, protection and reforestation of riparian areas is critical for preventing severe stream degradation. Narrow buffers alone, however, are not adequate to protect biological integrity in streams draining highly urban basins.

The Extent of Perennial Streams in the Puget Lowland

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Perennial streams define the extent of aquatic habitat during summer in the Puget Lowland. The spatial extent of perennial streams may be an important control on biological processes (e.g., primary production) and conditions (e.g., the population levels of aquatic species) in streams and may also be influenced by urban development. Channel networks throughout the Puget Lowland were surveyed during summer base flow conditions to determine the extent of perennial flow. The survey results were analyzed in conjunction with other geographic information to identify the primary controls on the location of perennial streams. The advance outwash commonly forms aquifers in the region, providing a continuous source of water for streams. A spatial analysis revealed a 50 percent probability of perennial flow at points along a channel network where the drainage area is 1.2 sq km, however, there was a wide range in drainage areas for both perennial and ephemeral reaches. Surfical geology provides a more reliable indicator of perennial and are typically found near the contact between glacial till and advance outwash deposits. The influence of land use and other topographic factors was not evident.

Returning Watershed Functions to the Urban Landscape: Current Approaches Being Evaluated by the City of Seattle

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What stormwater management techniques are really available to cities that are fully urbanized? The effects of urbanization on creek ecosystems are well known. Common knowledge and practical research have pointed to the importance of riparian buffers, upper watershed detention, and both structural and behavioral Best Management Practices (BMPs). However, in a fully urbanized city such as Seattle many, if not the majority of these techniques are not feasible. Fully built-out conditions severely limit land available for riparian buffers or detention facilities. In addition, the high density of underground utilities (electricity, water, drainage, sewer, and telecommunications) can frustrate effort to install structural BMPs. Despite the inherent difficulties, Seattle Public Utilities (SPU) has embarked on several projects to evaluate stormwater management alternatives designed to mimic the physical, biological and chemical functions that are integral to a healthy creek ecosystem. One area of focus for stormwater management alternatives is the public right-of-way. This presentation will describe stormwater management techniques appropriate for an ultra-urban environment.

SESSION 8A: NON-INDIGENOUS MARINE SPECIES, ROOM 407-409

Introduced Marine and Maritime Species of the Pacific Northwest: Historical Pathways and Current Patterns

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Introduced species are multiple ecosystem stressors, altering community structure and threatening native species worldwide. Documenting the history, patterns and status of introduced species is essential for identifying dominant pathways and prioritizing control efforts. In an extensive survey of the recent and historic literature we found >140 records of established introduced marine and maritime species in the Pacific Northwest, >50 cryptogenic species (i.e., of uncertain origin), and >20 records of transient non-native species. Most species are invertebrates from 11 phyla (>100 introduced species, >40 cryptogenic, >20 transient); vascular plants (27 introduced, 2 cryptogenic), algae (4 introduced, 6 crytpogenic), fish (4 introduced), and protists (4 introduced, 3 cryptogenic) are also present. Most species have had few documented ecological and economic effects, but some have had notably dramatic impacts. Historically, the major pathways of introduction to this region were oyster shipments and ship hulls (invertebrates and algae) and intentional plantings (vascular plants). Currently, the major pathway is most likely ballast water transport in commercial vessels. As the number of introduced species increases in other North American coastal ports, the short-distance spread of invaders from these nearby hubs is likely to increase.

Marine and Estuarine Non-indigenous Species in the Strait of Georgia, British Columbia

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Dorothee Kieser
Glen Jamieson
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University of British Columbia

The Strait of Georgia on the west coast of Canada is an important inland sea for seafood production, recreational activity, and maritime industry. In this paper we review the presence and role of non-indigenous species (NIS) in the ecosystem of the Strait. Based on the literature and authoritative personal communications, we estimate the following number of NIS have established populations in the Strait or along its shoreline : algae - 22; vascular plants- 22; invertebrates- 65; fish - 3; birds - 1; mammals - 1. Some of the species' records may only represent range extensions and other species may be cryptogenic. Because of the lack of ecological surveys and monitoring in the Strait there is uncertainty about when most of the NIS arrived in the Strait, modes of introduction, and ecological impact. However it is clear that numerous species arrived as hitchhikers with oysters (*Crassostrea gigas*), which were intentionally introduced. Other species may have arrived via ballast water, ship fouling, releases of live food organisms, the plant nursery and aquarium trade, and research and teaching activities. Because of the multiple pathways available for NIS to spread into the Strait, it is difficult to implement comprehensive effective control mechanisms to minimise or prevent any introductions. However there are programs in place such as quarantine procedures, ballast water control and management, and public education which could be expanded to help reduce the risk.

Patterns of Plant Species Abundance and Physical Conditions in Marine Habitats Invaded by the Non-indigenous Cordgrass, *Spartina anglica*, in Puget Sound, Washington

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Washington State University Vancouver

The nonindigenous English cordgrass, *Spartina anglica*, was introduced into northern Puget Sound, Washington, in 1961. This species can invade four different habitat types: low and high salinity marshes, mudflats, and cobble beaches. We measured the relationship between *Spartina* abundance and other plant species, soil physical conditions, and intertidal height at a number of invaded sites. At low salinity marshes, *Spartina* grows in the middle intertidal where it forms a monoculture displacing other native plant species. At high salinity marshes, *Spartina* is restricted to the lowest intertidal zones where it captures sediment and extends the low marsh out into former mudflat habitat, but we have not observed monocultures forming. At mudflat habitats, *Spartina* is restricted to high intertidal sites where it creates a raised marsh habitat and facilitates the establishment of several previously absent plant species. To understand the effects of *Spartina* on soil conditions, a number of soil variables were measured in areas with *Spartina* and those where it has been removed. We found lower water content, lower redox potential and higher salinity in soils without *Spartina*. Because of the unique role it plays in Pacific Northwest estuaries, *Spartina* has created significant changes to invaded Puget Sound marine communities.

The Control and Regrowth of the Non-indigenous English Cordgrass, *Spartina anglica*, in Puget Sound, Washington

Tabitha G. Reeder, Casey Gozart, C. Eric Hellquist, Megan N. Dethier, and Sally D. Hacker
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Spartina anglica, the English cordgrass, was introduced into northern Puget Sound in 1961. The Washington State Department of Agriculture Noxious Weed Control Board is responsible for control of *Spartina*. Control efforts involve mowing, hand pulling, and herbicide treatment. Very little information exists on the effectiveness of control or possibility for reinvasion. In June 2000, we set up 0.25 m^2 permanent plots to monitor control and reinvasion of *Spartina* in mudflats, cobble beaches, and low and high salinity marshes. Sites varied in the number of years of control. We measured the percent cover of *Spartina* and other plant species, and physical factors both with and without *Spartina* removal. Our data suggest that without removal, *Spartina* can form monocultures. With five years of control, *Spartina* cover was significantly reduced in contrast to sites with fewer years of control. While two–year removal showed reduced *Spartina* cover and higher plant species diversity compared to one–year removal plots, there was still significant *Spartina* cover at these sites. In addition, with *Spartina* wrack present, regrowth is significantly reduced even with only one–year of removal. Removal also influenced the soil characteristics in that sites with *Spartina* removal had lower oxygen content but similar salinity.

SESSION 8B: MARINE PROTECTED AREAS, ROOM 405-406

Developing a Collaborative Process to Establish Marine Protected Areas

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XwaYeN (Race Rocks), as Canada's first Ocean Act MPA, was recommended for designation based on a series of recommendations that were developed through a collaborative process. This process had a number of distinctive features and quite remarkable results. Was the process based on authority or interests? How do you bring a disparate spectrum of interests together to establish consensus-based recommendations for conservation and protection? As a case study, the XwaYeN experience offered many lessons and has encouraged a wide range of interests to describe their own process and vision for further MPA designations.

Zoning to Protect Resources Within the Olympic Coast National Marine Sanctuary

Liam Antrim
Olympic Coast National Marine Sanctuary

The Olympic Coast National Marine Sanctuary covers approximately 3,300 square miles of the outer coast of Washington. Although this area was granted a federal designation as a sanctuary in 1994, relatively few restrictions were imposed on activities within the Sanctuary. Prohibited activities are limited to overflights below 2000 feet, oil drilling, extracting of ocean minerals, laying of pipelines, discharges and deposits of materials, and taking of marine mammals, reptiles, and birds. Whereas these restrictions do provide a level of protection to meet the Sanctuary's mission of ecosystem-wide conservation of ecological and historic resources, activities such as bottom trawling and harvest of intertidal resources continue to occur in ways that may contribute to habitat degradation. The Sanctuary initiated a process to evaluate the need for more restrictive levels of zoning in an effort to provide more comprehensive protection and conservation of marine habitats and biota. This process began with establishment of a Marine Conservation Working Group that is developing a proposal for intertidal zoning within the Sanctuary. A critical aspect of this process is collaboration with other state and federal agencies with jurisdiction, as well as with tribal governments with reservation lands adjacent to the Sanctuary and sovereign rights to harvest the resources. The process by which zoning recommendations were developed included drafting a statement of purpose and goals for zoning, review of ecological information on the study area, identification of site selection criteria, use of georeferenced habitat and biological data, and development of alternative zoning schemes for consideration. A public outreach process was also implemented to inform and solicit input from the potentially concerned and impacted public.

Voluntary Marine Protected Areas and Adaptive Management in the San Juan Islands

Richard W. Osborne, Kari L. Koski and Rowann E. Tallmon
The Whale Museum

Two types of voluntary Marine Protected Areas (MPAs) have been developed in San Juan County. The first type, designed to manage whale watching, is a mobile species-specific MPA that applies only when orcas are present. The second type of voluntary MPA are Bottomfish Recovery Zones designated by San Juan County.

The integrity of an MPA depends upon compliance. In the San Juans most existing MPAs designated by top-down legislation haven't received adequate funding to monitor or enforce them. In contrast, the new voluntary MPAs are implemented through "peer pressure" and on-the-water education programs.

A primary tenet of "adaptive management" is flexible management that is modified for changing conditions. Top-down MPAs require legal enactment and legislated funding for education, monitoring, enforcement and prosecution. If regulations prove to be ineffective, adjustments require further legislation. This inflexible process makes regulated MPAs impractical for applying adaptive management.

Because voluntary MPAs have no legal standing, local communities can propose them or adjust them at any time. In terms of adaptive management, voluntary MPAs provide the flexibility required to adjust management strategies when needed and can do so with less cost and better compliance.

Opportunism and Optimality: Strategies for Developing Marine Protected Area Management in Washington

David Fluharty
University of Washington

This paper explores the history, status and future directions for elaboration and management of Marine Protected Areas (MPAs) in Washington State. Considerable effort is being invested by federal, state and local entities and tribes to utilize marine zoning in management actions. In many cases, these zones and their management objectives qualify for definition as MPAs. Establishment of MPAs in Washington has been largely opportunistic - resulting in a patchwork of relatively small areas with partial protection and a few larger areas where protective management is potential. Currently, interest in improving the performance of marine resource management, e.g., in fisheries, wildlife, shellfisheries and marine pollution includes examination of MPAs as a tool with possibly a more wide-spread application. Development of a network of MPAs, for example, requires and more coordinated, comprehensive and prioritized (optimal) approach, especially given limited resources.

SESSION 8C: TOXICS IN MARINE MAMMALS, ROOM 402-403

Organochlorine (OC) Compounds in British Columbia Marine Mammals—An Overview of Trends And Concerns

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This paper reviews the information available about the major groups of organochlorine (OC) compounds in some BC marine mammals. Most data pertain to harbour seals (*Phoca vitulina*) and to killer whales (*Orcinus orca*) but a few analyses have been carried out on stranded and dead animals of other species. The OCs studied have been mainly the polychlorinated dibenzo-*p*-dioxins and furans (PCDD/F), analysed mainly in response to concerns about the impact of pulp mill discharges) and the DDT-group of insecticides and the polychlorinated biphenyls (PCBs); the latter groups have been analysed for more general environmental interest.

Harbour seals from the Strait of Georgia contained high PCDD/F concentrations in the early 1990's, most probably in response to contamination of their food web by compounds discharged from the coastal pulp mills situated in the Strait. Harbour seals from a "reference" site in western Vancouver Is., not contaminated with pulp mill PCDD/F, contained much lower residue concentrations which were comparable with data recorded from uncontaminated sites in eastern Canada, western Europe and the Arctic. Preliminary analyses suggest that PCDD/F concentrations in Strait of Georgia harbour seals may be declining, in response to the reduction in PCDD/F discharges from coastal pulp mills which began in the early 1990's. Concentrations of PCBs in one group of killer whales from the Strait of Georgia (sampled in the early to mid 1990's) were very high, and the route of exposure and uptake of PCBs by this group is currently under investigation. Toxic equivalents (TEQ) derived from both the PCB concentrations in killer whales, and PCDD/F concentrations in harbour seals from the Strait of Georgia exceeded the threshold inferred for disruption of normal immune function during experimental feeding studies on captive harbour seals, and this raises concerns about the general health of these marine mammal groups and of the ecosystem of which they are a part.

Temporal Trends in Contaminants in Puget Sound Harbor Seals

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Studies of harbor seals provide some of the most consistent data on long term trends in contamination in Puget Sound. We examined trends in contaminants using samples from harbor seal pups collected at 4-5 year intervals from 1972 through the late 1990s in Puget Sound and the Strait of Juan de Fuca. Harbor seals are ideally suited for trend analyses because they are highly contaminated, integrate contamination in a broad selection of prey, and, with proper sample selection, provide low inter-sample variability. We determined levels of a broad range of chlorinated hydrocarbon contaminants including congener-specific concentrations of PCBs, DDTs and other pesticides, and polychlorinated dibenzo dioxins and furans (PCDDs and PCDFs). We tested both the most recent samples and re-tested some of the historical samples from 1984 and 1990 to provide more detailed data on historical contaminants. While concentrations of PCBs and DDT have declined dramatically since the 1970s, concentrations have stabilized since the mid-1980s with only slight declines since then. Even though concentrations have declined, harbor seals are clearly still at risk, with the current concentrations of PCBs and the TEQ in pups within the range identified as causing immunotoxicity in seals. Most of the TEQ came from PCBs

rather than PCDDs or PCDFs. New analyses are currently underway.

PCBs at the Top of the Food Chain: Geographical Variation in British Columbia And Washington Harbor Seals

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Marine mammals often occupy high trophic levels in food chains, and are therefore prone to accumulating high concentrations of many toxic chemicals. Exposure to such contaminants as polychlorinated biphenyls (PCBs) dioxins (PCDDs) and furans (PCDFs) have been associated with endocrine disruption, reproductive impairment, immunotoxicity and developmental abnormalities in several marine mammal populations inhabiting European and North American coastal waters. We have been using harbor seals as sentinels for chemical contamination in southern British Columbia and Puget Sound, Washington for several years. Small blubber biopsy samples from young, healthy, free-ranging harbor seals inhabiting several areas in BC and Washington have been analyzed for congener-specific PCBs, PCDDs and PCDFs. Our results suggest that the Puget Sound food chain is particularly contaminated with PCBs. In British Columbia, a pulp mill-derived signature of contaminants (particularly PCDDs) was detectable, although levels have been declining since the implementation of strict regulations on the use of chlorine in the bleaching process in the late 1980s. The persistent PCBs remain a concern to the health of wildlife in the waters of both British Columbia and Washington, despite the implementation of regulations in both Canada and the US in the mid-1970s.

Organocholrine Contaminants in River Otter Collected from Puget Sound, Washington, 1996

Robert Grove
Oregon State University

SESSION 8D: HARMFUL ALGAE, ROOM 404

Department of Health's Biotoxin Monitoring Program

Frank Cox
Washington State Department of Health

Washington state routinely experiences seasonal restrictions of commercial and recreational shellfish harvest due to the marine biotoxins Paralytic Shellfish Poison (PSP) and Domoic Acid (DA). The Department of Health (DOH), Office of Food Safety and Shellfish Programs monitors PSP and DA toxin levels throughout the state. The DOH closes areas to the recreational and commercial harvest of shellfish when DA levels exceed 20 ppm or PSP levels exceed 80 µg toxin/100 gm shellfish tissue. The Department's role in monitoring these marine biotoxins is to prevent risk to the consuming public, through closure of commercial harvesting and through public notification of recreational harvesters. Significant changes have occurred in harmful algal bloom (HAB) activity since the inception of PSP monitoring in Washington in 1942. Some of these include an expansion of *Alexandruim*'s presence, from it's original detection site in the Strait of Juan de Fuca, into the Puget Sound. This expansion in bloom activity has progressed steadily, first moving into north Puget Sound and central Puget Sound through the 1960's and 1970's, and eventually reaching south Puget Sound in the 1980's. A few areas remain unaffected by PSP, including Hood Canal and the southernmost extremes of south Puget Sound. Newer trends in PSP bloom activity show increasing toxin levels, and oscillations bloom activity. Domoic Acid was first detected in 1991 off the pacific coastline. DA continues to occur annually, although activity remains low during most times of the year. The DOH marine biotoxin monitoring program has grown in response to these bloom activities. At its inception in 1942, monitoring was performed between the months of April through September, with an average of 200 samples analyzed yearly. Presently, all areas are monitored; some are seasonal while others are year-round, with an average of over 3000 PSP samples and 1500 DA samples analyzed annually.

Detection of Domoic Acid in the Lab and Field

Vera Trainer
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Cochlodinium polykrikoides: A New Killer of Farmed Salmon in British Columbia

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Blooms of *Cochlodinium* were monitored for the first time on the west coast of Vancouver Island from August to October 1999. They caused substantial mortality to farmed salmon with losses estimated at $2 million. Surface concentrations of 60,000 cells ml^{-1} peaked in early September. Strong diurnal pattern was observed in blooms at farm sites with high cell concentrations overnight at depths to 25 m and at the surface during the day. Fish stopped feeding when cell counts exceeded 500 cells ml^{-1} in the netpens, and mortality was observed above 2000 cells ml^{-1}. Bioassays in the field with Atlantic salmon, *Salmo salar*, smolts demonstrated lethality after 120 min exposure and over 90 percent mortality after 500 min when cell concentrations varied from 10,800 to 2,700 cells ml^{-1} as the bloom moved through the test site. Under controlled laboratory conditions *Salmo salar* smolts died within 27 min with exposure to 7,200 cells ml^{-1}, 55 min with 3,400 cells ml^{-1}, and although fish appeared distressed in 1,000 cells ml^{-1} only 20 percent died within the 24 h bioassay. Data from monitoring of harmful algae at farm sites in 1999 and 2000 tends to suggest an increased distribution of this ichthyotoxic species on the west coast of Vancouver Island.

Macroalgae Blooms and Impact to Nearshore Habitat and Resource in the Strait of Juan de Fuca

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Macro algae blooms form dense mats which reduce light and oxygen, creating an anoxic environment. These blooms, promoted by nutrient loading, have been documented in other parts of the world to precipitate dramatic changes to nearshore ecosystems. Macroalgal blooms in inland marine waters of Washington (known locally as 'ulvoid blooms') are theorized to be increasing, and are documented to occur in areas critical for a number of federally listed salmon species, including Puget Sound Chinook, Hood Canal summer chum, and bull trout. In particular, embayments of the Strait of Juan de Fuca, the focus of a regional, citizens based marine initiative to restore and protect nearshore environments, are experiencing large ulvoid blooms. Unfortunately no information exists on the history, or impact of, ulvoid mats of Washington state, or the Strait of Juan de Fuca.

This paper will present findings of a long term study defining for embayments of the Strait of Juan de Fuca: 1) Trends of ulvoid mats, 2) Habitats changes associated with ulvoid mat blooms, and; 3) Response of critical shell and finfish resources of the Strait of Juan de Fuca. It will also offer direction on the critical role citizen based work in management of nearshore environment.